

DEC STD 105-0 Display Workstation Ergonomics (Human Factors): Design Criteria

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ABSTRACT: This standard provides operators with the best terminal and workstation designs based on available knowledge, and it provides design criteria, comments, and recommendations.

APPLICABILITY: This standard is mandatory for all Digital employees principally those involved in the design, but also those involved in the purchase, manufacture, support, and maintenance of displays, keyboards, document holders, and workstations with their components.

STATUS: APPROVED 31-Jan-1992; use VTX SMC for current status.

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1 INTRODUCTION

The comfort, well-being, and productivity of operators are prime considerations in the design and manufacture of terminals and workstations. Several variables must be dealt with to ensure the optimization of this human-computer interface. Display work stations generally include a typewriter-like keyboard and a visual display unit (VDU) as the means of communication between operator and computer system. These devices must be designed to ensure optimum performance. To ensure that the operator is comfortable, seating, lighting specifications, ventilation, and acoustics (see *DEC STD 104-0 Product Acoustic Noise Limit*) must also meet the operator's needs.

DEC STD 105-0 Display Workstation Ergonomics (Human Factors): Design Criteria is based on a growing understanding of the physiological mechanisms leading to operator performance, comfort, and fatigue. These mechanisms fall into musculoskeletal (postural and hand motion), ocular (visual), and cognitive categories. This understanding results from numerous field surveys of computer terminal installations, laboratory research into specific physiological mechanisms, and legal and de facto standards written on the basis of research and expert opinion. These studies have been undertaken worldwide, and all of them conclude that proper ergonomic design and use is effective in measurably decreasing discomfort and increasing productivity.

There are many standards pertaining to the ergonomic requirements of the design and use of video display terminals and workstations. Among the most comprehensive and influential standards are: *American National Standard for Human Factors Engineering of Visual Display Terminal Work Stations* (ANSI/HFS 100-1988, United States); *Safety Regulations for Display Work Places in the Office Sector* (ZH 1/618 Edition: 10/80, Germany); and Parts 1, 2, 6, and 9 of *Deutsches Institut für Normung (DIN) Standard 66234* (Germany). The neutral testing institute Technischer Überwachungs-Verein (TÜV) is responsible for tests for conformance to the ZH 1/618 standard. TÜV is authorized to grant the GS mark to those products that comply with the ZH 1/618 and other safety and nonsafety standards.

DEC STD 105-0 embodies those findings that are either well-established and suitable for design or mandated by Ergonomic Regulatory Standards. As additional studies further establish or substantiate these data, the resulting guidelines will be upgraded to standards and moved to DEC STD 105-0.

1.1 PURPOSE

This standard establishes human factors (ergonomics) standards for designing and manufacturing displays, keyboards, document holders, and workstations. The requirements of this standard are intended to ensure comfortable, productive, and long-term use of such devices by a wide range of users in a variety of settings. If products meet or exceed (where appropriate) the standards in DEC STD 105, they will be assured of complying with current national and international standards.

This standard does not discuss acoustics, heat, fire, emissions, and safety standards, which are treated elsewhere, and it does not address issues concerning the physical arrangement and layout of equipment in the workplace. Equally, this standard does not address psychological and organizational factors that can be as relevant as physiological mechanisms to the efficiency of the worker.

See *DEC STD 102-4 Environmental Standard for Computers and Peripherals: Product Acoustics Noise Measurement*; *DEC STD 103-0 Electromagnetic Compatibility (EMC) - Overview and Process Requirements*; *DEC STD 104-0 Product Acoustic Noise Limits*; *DEC STD 107-1 Digital Standard for Terminal Keyboards - Registry of Graphic Character Sets*; *DEC STD 107-2 Digital Standard for Terminal Keyboards - LK201 Character Sets and LK250 Character Sets*; *DEC STD 119-0 Digital Product Safety: Introduction and General Requirements*; *DEC STD 119-1 Digital Product Safety: Design Criteria*; and *Introduction to Displays For Managers and Operators*, Digital Part No. EF A0765 50/90 05 20 30.0 CTS.

1.2 SCOPE

The requirements of this standard apply to all Digital visual display units (regardless of technology), keyboards, document holders, and workstations whether they are designed by Digital or are selected and sold by Digital. This standard, in general, applies to Digital products intended for use in offices, but heads 6, 7, and 8 apply to a wider range of products. Consult the Ergonomics Domain Manager if additional information is required.

1.3 RESPONSIBILITIES

The Corporate Human Factors Engineering group is responsible for:

- a. Maintaining this standard and assisting users in its interpretation and use
- b. Providing guidance and verification testing in accordance with this standard, when funded by Product Development or other groups.

The engineer responsible for the product is responsible for ensuring:

- a. Product design goals are defined so that products will comply with the applicable topics as defined in DEC STD 105-0.
- b. Goals are published in the Phase Review, Phase 0 Product Requirements document.
- c. The product is designed to meet these goals.
- d. Sufficient funding and other resources are provided to support these activities and the verification testing (both internal and external).

The product manager is responsible for the product's meeting marketing and ergonomic requirements. If it is necessary that the product design or method of measurement deviate from the requirements of this standard, the engineer responsible for the product is responsible for obtaining the waiver.

NOTE

***DEC STD 066-2 Waivers to Digital Design Standards* establishes the procedures that are necessary to prepare, review, approve, and control waivers to the technical requirements of this standard.**

DEC STD 105-0 represents the best available interpretation of the national and international ergonomics standards to date. However, the testing organizations responsible for certification (for example, TÜV) have evolving checklists that are used in the evaluation process. Therefore, there may be discrepancies between the requirements defined by a standard and the final tests for compliance. In order to minimize this occurrence, every effort will be made by Corporate Human Factors Engineering Department to maintain contact with members of the testing organizations to obtain the latest interpretation of the

applicable standards. Contact the Corporate Human Factors Engineering Department for more information.

1.4 COMPLIANCE

Compliance with this standard can be achieved by either:

- a. Having the Corporate Human Factors Engineering Department perform the measurements required to verify that the values of the parameters listed in the standard have been achieved; or by
- b. Having the hardware design team perform the verification measurements under the supervision of a representative of the Corporate Human Factors Engineering Department.

The equipment tested may be an engineering prototype, a pilot production sample, or a production sample, provided that the tested equipment is representative in all relevant aspects of the final product.

Compliance will be determined using the default parameters of the system under verification (for example, character sets, colors, configurations, system options, and operator settings).

Compliance with this standard may depend on hardware, software, and workstation elements. Although one or more of the elements of a system may have already passed the verification testing, the product group using any given combination of such elements shall be responsible for compliance of the configuration offered for sale.

If the product(s) fails to meet requirements, the engineer responsible for the product is responsible for initiating the changes required to upgrade the product to the specifications required in DEC STD 105-0 or obtaining a waiver.

2 OBSOLETE DOCUMENTATION

Listing of Legal Status of Ergonomic Standards, May 1986, is now obsolete. Contact the Ergonomics Domain Manager for the current status of ergonomic standards external to Digital.

3 FIFTH PERCENTILE THROUGH NINETY-FIFTH PERCENTILE POPULATIONS

This standard attempts to provide for all but the extreme ends of the adult male and female users of Digital products. Where feasible, it is desirable to extend the range wider to include people with disabilities.

4 VISUAL DISPLAYS

This section deals with visual displays and covers the topics of adjustability, antiglare treatments, color of monochrome displays, spatial, temporal, and chromatic factors, character size and spacing, coding of displayed information, distortions of the displayed image, and visual display housing surfaces.

All units of luminance and distance reported in this standard are in the international units of candelas/square meter and millimeters. The following conversions may be used where appropriate: 1 footlambert (fl) = 3.426 cd/m²; 1 inch = 25.4 mm; 1 foot candle (fc) = 10.8 lux (lx).

4.1 ADJUSTABILITY

4.1.1 Display Tilt and Swivel

Definition/Measurement: Tilt is the vertical angle of the display screen. Swivel is the left and right rotation of the display screen. Both angles can be measured using a standard protractor.

Standard: Both the tilt (down) and swivel shall be adjustable. The range of tilt adjustment (up) shall be at least 5° forward and greater than or equal to 20° backward. The monitor must be stable in all tilt and swivel positions. The minimum angle of rotation shall be plus and minus (left and right) 50°. The maximum angle of rotation shall be plus and minus 180°.

Recommendations: The backward tilt of the display screen should be adjustable through as wide a range as possible. The greater the range of swivel of the display screen, the more flexibility the user has in positioning the display. However, the angle of rotation should be limited to plus and minus 180°, or slightly more, to prevent tangling of cables attached to the display.

4.1.2 Display Height

Definition: This height is the distance from the top raster line of the display to the worksurface on which the display rests. The purpose of stating a standard for this distance is to ensure that the top line of a display is no higher than the eye height of a seated user, since looking up at a display for extended periods can induce neck strain.

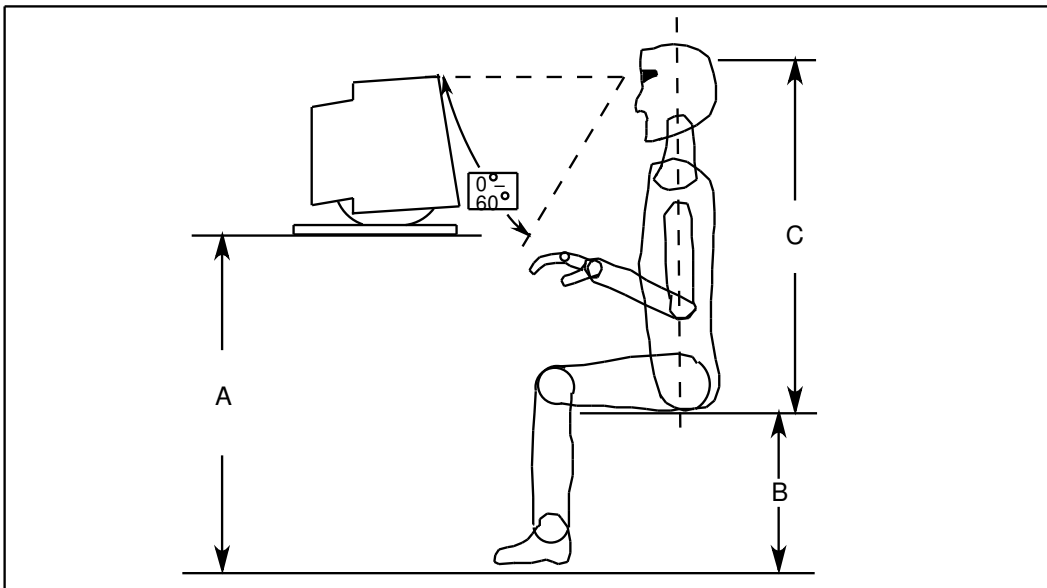
Whether or not the top line of a display is higher than the eye height of a seated user is dependent upon many factors. Among these factors are the vertical size of the display, the height of the worksurface on which the display rests, the height of the chair in which the user sits, and the seated eye height of the user. Since there are so many variables involved in determining display height, it is difficult to determine a limit to display height that satisfies all possible conditions.

Standard: The DIN 66234 standard requires that if the display height is not adjustable, the display height (as defined above) shall be less than or equal to 500 mm (19.69 in). If the height of the display is adjustable, the lowest height shall be less than or equal to 500 mm (19.69 in) and the highest height shall be less than or equal to 610 mm (24.02 in). This means that the range of adjustment shall be at least 110 mm (4.33 in). Currently, in order to pass the ergonomic requirements of ZH 1/618 (as assessed by (TÜV)), this standard must be adhered to. However, exceptions will have to be made for very large vertical display areas.

The DIN 66234 standard bases the recommended heights on what is described as the sitting eye height of the 5th percentile female, and the sitting eye height of the 95th percentile male. However, when these actual values are used in the computation of the maximum display height, different values are obtained (see Discussion).

Recommendation: Large displays should not be designed to be placed on system boxes as this will probably increase their height beyond that of the 5th percentile female. The guiding principle for this standard is that the display must be positioned so that those areas of it to be viewed continuously may be viewed with a line-of-sight angle between horizontal (0°) and 60° below horizontal as shown in Figure 1.

Figure 1: Positioning of the Display Within the Visual Field and the Factors That Must Be Considered When Determining the Proper Value for Display Height.



Discussion: Referring to Figure 1, the following values can be defined. A is the height of the worksurface, B is the compressed seat height (for purposes of the following calculation the seat height is assumed to be adjustable to accommodate both the 5th percentile female and the 95th percentile male), and C is the seated eye height of the user. Given this arrangement, the maximum display height is determined by $B + C - A$. A common value for A (in Europe) is 720 mm (28.35 in). This dimension is higher in the U.S., up to 750 mm (29.5 in). The values for B and C are shown in Table 1 for the 5th percentile female. The maximum display height is then computed to be 405 mm (15.94 in) + 675 mm (26.57 in) - 720 mm (28.35 in) = 360 mm (14.17 in). This distance is the maximum display height if the height is not adjustable.

If the display height is adjustable, it must be adjustable to a minimum of no more than 360 mm (14.17 in). The maximum height of the display is based on the values of B and C for the 95th percentile male. Given the values in Table 1, this maximum is computed to be 520 mm (20.47 in) + 844 mm (33.23 in) - 720 mm (28.35 in) = 644 mm (25.35 in). This adjustable height means that the adjustability can be 644 mm (25.35 in) - 360 mm (14.17 in) or 284 mm (11.18 in).

Table 1: Values Used to Complete Display Height

	B	C
5th percentile female	405 mm (15.94 in)	675 mm (26.57 in)
95th percentile male	520 mm (20.47 in)	844 mm (33.23 in)

Note: All values are from Appendix B in ANSI HFS-100-1988.

4.2 ANTIGLARE

Definition: Glare is defined as either specular or diffuse reflections of ambient light sources from the front surface of the display. These reflections produce a veil of light that reduces contrast. Glare may reduce visual performance and visibility as well as causing discomfort. Glare is very dependent not only on the properties of the display screen but also on the lighting conditions of the workplace.

Standard: Antiglare treatment in the design of displays must be provided. The treatment may be either directly bonded to the display surface or attached securely. Only colorless or neutral gray antiglare treatment can be provided for color displays, without distorting the colors. Any antiglare treatment shall be such that the treated image complies with the requirements of resolution, luminance, background luminance, contrast, and percent raster modulation as defined by this standard.

Recommendation: In order to be effective, antiglare treatments must be able to adequately disperse any specular glare and provide contrast enhancement. Research in the area of glare control provides data that indicate the best available antiglare filter is a quarter wavelength optical filter combined with a suitable neutral density filter bonded directly to the display surface. Special considerations must be given to display surfaces that are designed to be touched during normal, intended use.

4.3 COLOR OF MONOCHROME DISPLAYS

Definition: The color of a display for monochrome displays

Standard: For monochromatic displays, the choice of green or amber in addition to a black-and-white display will accommodate a reasonable range of user preferences.

Some types of noncathode ray tube displays are of a different color from the three stated above. For these displays, dominant wavelengths above 650 nm should be avoided because protanopics (red-blind people) are noticeably less sensitive to these wavelengths. Similarly, blue phosphors should be avoided because of the lack of acuity of the eye in this region.

4.4 SPATIAL AND TEMPORAL FACTORS

To ensure that the information displayed on a video display is of acceptable quality to the human eye, several display parameters must be set to at least minimum values. The proper definition of these display parameters is related to the technique used for their measurement. Given this dependency, the general measurement techniques that are common to several of the parameters will be described first. This strategy will make certain that everyone who uses this standard will do so with a common understanding of each of the topics. Most methods of measurement are adapted from the *ANSI/HFS 100-1988 United States, American National Standard for Human Factors Engineering of Visual Display Terminal Work Stations* or *DIN 66234 Display Work Stations* standards.

Measurements of resolution, character luminance, background luminance, and contrast can be obtained from the results of a single microphotometric measurement. In these measurements, the luminance profiles (line-spread functions) are measured across the height of a horizontal line that is one pixel wide.

This measurement produces the line-spread function shown in Figure 2. This technique can also be used to measure the pixel width (stroke width) or height (depending on the direction of the line and the resulting scan direction) as shown in Figure 3.

Figure 2: Signal and Background Luminance Determination

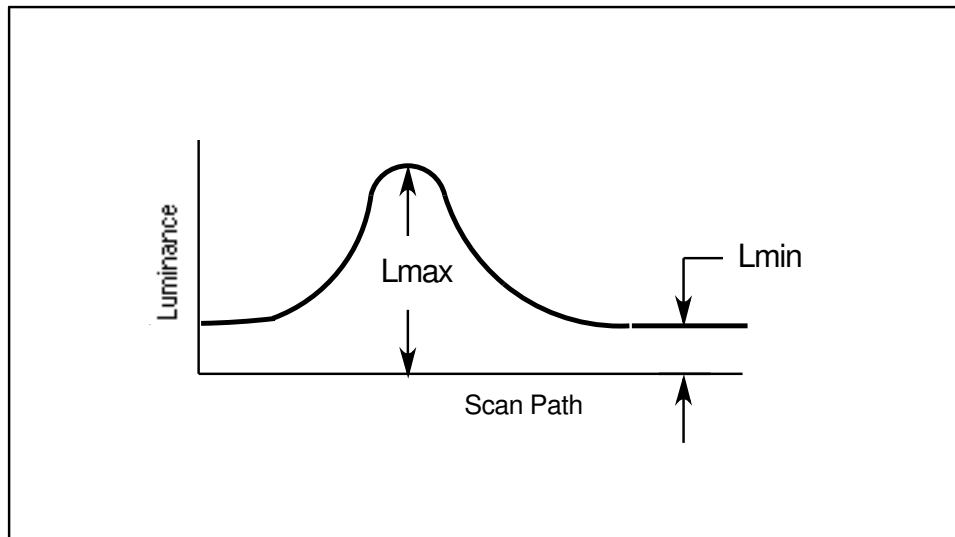
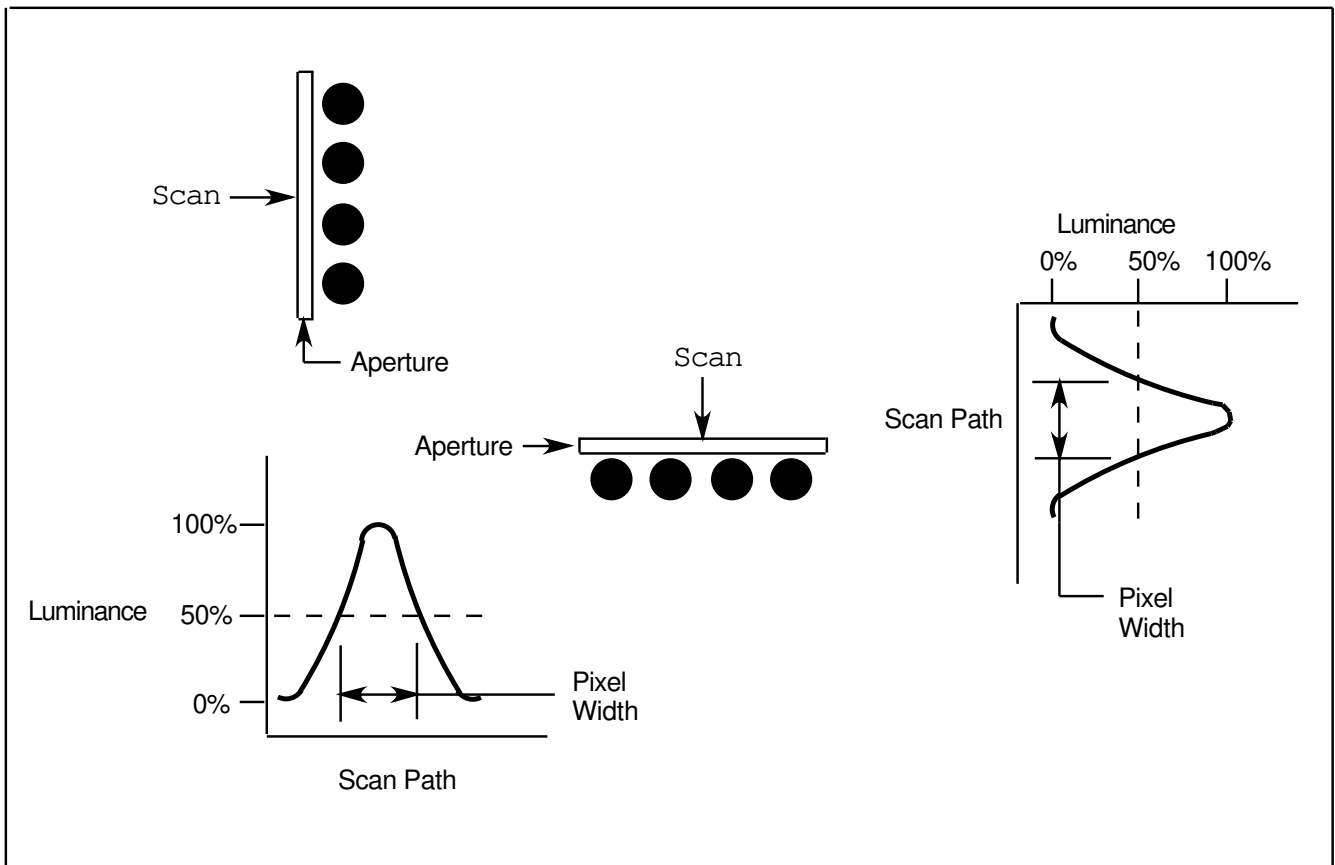


Figure 3: Pixel Width and Height

All measurements to test for conformance will be done in the illuminated test condition described as follows unless otherwise indicated. All measures of luminance correspond to L_{max} and L_{min} as shown in Figure 2.

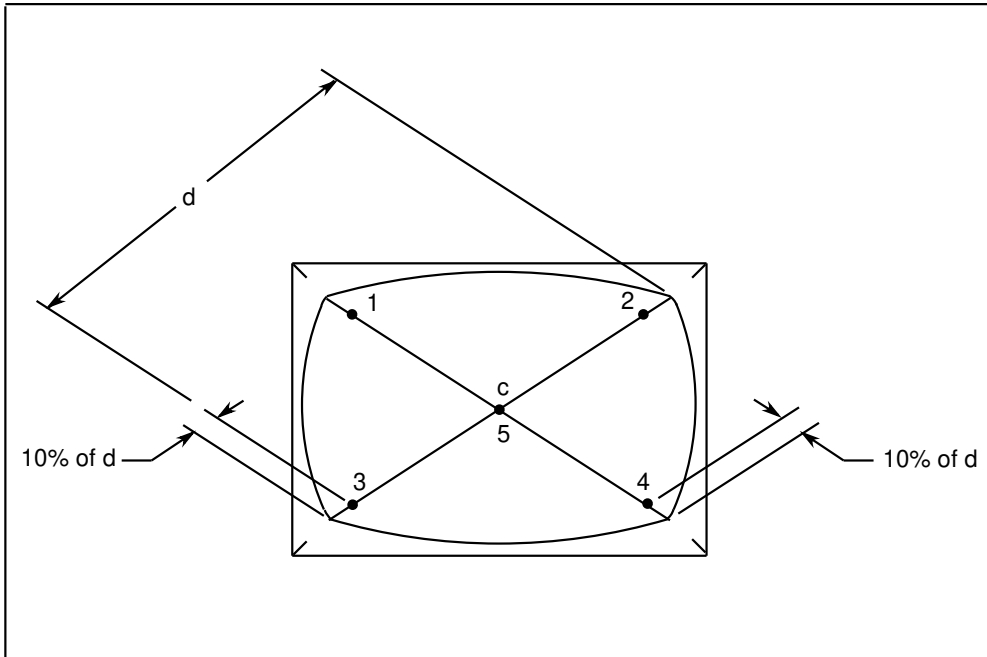
Illuminated Test Condition — The display shall be turned on for at least 15 minutes prior to the measurements. The illumination shall be measured on a plane tangent to the center of the display, at the center of the display when the tangent plane is perpendicular to the worksurface. The illumination shall be 250 lux plus or minus 10%. The microphotometer shall be positioned so that it does not shadow the display.

Measurement Locations — Measurements of resolution, character luminance, background luminance, contrast, luminance uniformity, character size and spacing (subhead 4.5) shall be made at the five locations on the screen as shown in Figure 4. These locations are as follows:

1. At the center of the screen (c). The center is defined as the intersection of the two diagonals.
2. At locations in each corner of the screen at a distance of 10% of the diagonal length (d) from the corner point of the used surface area.

All topics defined in this standard shall meet or exceed the required values at all five locations.

Figure 4: Five Screen Locations Used for Measurement

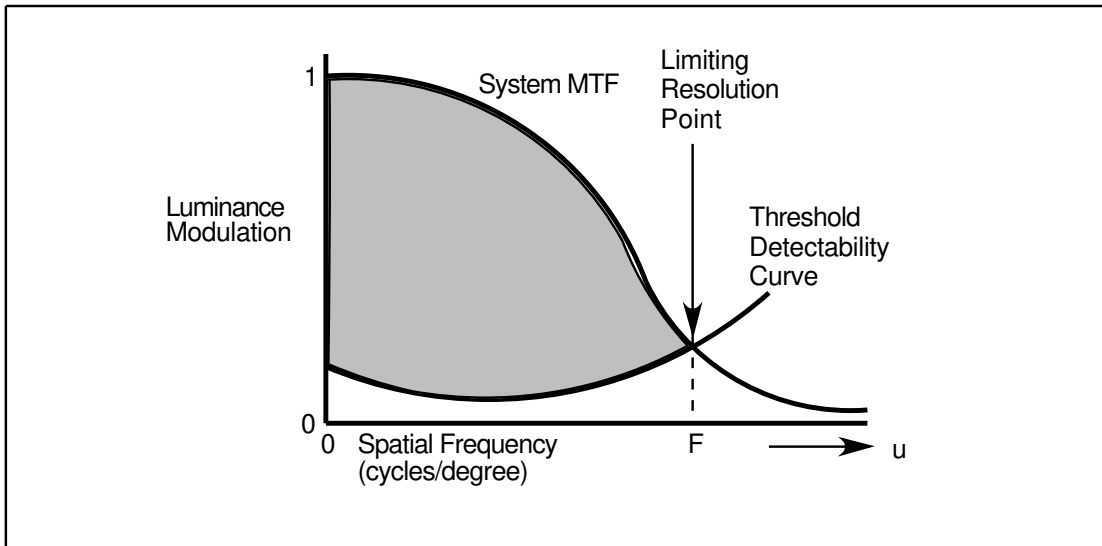


4.4.1 Resolution

Definition/Measurement: The resolution of a display is a measure of the display's ability to resolve the smallest discernible details. Therefore, the measurement of resolution must take into account the capacity of the human visual system to perceive the displayable information. A measure of the resolution of a display that takes the human response into account is the modulation transfer function area (MTFA). This measure is used to define resolution as used in this standard.

MTFA is defined as shown graphically in Figure 5. The shaded area (MTFA) is bounded by two curves. These are the display system MTF curve and the human threshold detectability curve (TDC). The system MTF curve describes the capability of the display to present sine wave patterns of varying frequency, while the TDC is a description of the eye's ability to detect such patterns. Given these bounds, the MTFA describes the displayable spatial frequencies that can be perceived by a human operator.

Figure 5: Definition of Modulation Transfer Function Area (MTFA) for Monochrome Displays



Mathematically, the MTFA is defined as follows.

$$\text{MTFA} = \int_0^F [\text{MTF}(u) - \text{TDC}(u)] du,$$

in which F = the frequency at which $\text{MTF}(u) = \text{TDC}(u)$, or the limiting spatial frequency. A degree is the subtended arc measured from the design viewing distance.

$\text{MTF}(u)$ = the value of the display system MTF at spatial frequency u , and

$\text{TDC}(u)$ = the observer's threshold modulation at spatial frequency u .

At frequencies beyond the limiting spatial frequency (F), the visual system does not respond to the contrast (modulation) developed at the display; therefore, any further increase in display resolution is not perceived. Given these limits, the concept of MTFA is easily summarized. MTFA is simply the excess of signal (MTF) over the threshold requirements (TDC) of the visual system, integrated over all usable spatial frequencies.

The value of MTFA can be developed from microphotometric measurements of the line-spread function. For these measurements, the display intensity shall be adjusted so that the symbol or background luminance, whichever is higher, is equal to 45 cd/m², while maintaining a luminance modulation of at least 0.5 (contrast ratio of 3:1). (Luminance modulation is defined under subhead 4.4.4).

Standard: The MTFA metric of a display shall have a value of at least 7 cycles/degree. This corresponds to a spot size of approximately 0.5 mm (0.02 in). A preferred value is MTFA approximately or equal to 12 cycles/degree (0.3 mm [0.01 in]).

Recommendation: The MTFA of a display should be as high as possible.

Discussion: Although there are many other objective measures of resolution, the MTFA metric has been behaviorally validated for monochrome CRTs through several scientific studies.

NOTE

The ZH 1/618 standard requires that the displayed characters not touch each other and that the characters maintain a focused presentation at every setting of the character luminance. The test for this requirement has both subjective and objective parts. For this test, the luminance/contrast are turned "up" as far as possible. The presentation of characters is then inspected to see if they are focused and do not touch.

The following measurement may be required by the TÜV representative. This measurement is termed *inner contrast*. With the display at the maximum setting described above, a lower case *e* is placed in the middle of the display. Luminance measurements are taken of the inner area of the upper half of the letter *e* and of the character stroke. The computed contrast ratio for both negative and positive images must be greater than 2:1.

4.4.2 Luminance

Subhead 4.4.2 through subhead 4.4.7 use the ANSI definition of luminance and contrast. For the ZH 1/618 definition and requirements, see subhead 4.4.9.

Definition/Measurement: The maximum luminance (L_{max}), and the minimum luminance (L_{min}), can be determined as shown in Figure 2.

Standard: The luminance level must be user adjustable. Either the character or its background, whichever is of higher luminance (that is, L_{max} as shown in Figure 2), shall be able to achieve a luminance of at least 45 cd/m^2 in the illuminated test condition while maintaining a luminance modulation of at least 0.5. From this minimum value, the luminance must be adjustable so that at least a luminance modulation of 0.82 (contrast ratio of 10:1) can be achieved.

4.4.3 Background Luminance

Definition/Measurement: The standard for background luminance only concerns the display of light characters on a dark background. This luminance is measured under the illuminated test condition. The background luminance is defined as L_{min} shown in Figure 2.

Standard: When displaying light characters on a dark background, the luminance of the background shall be greater than or equal to 6 cd/m^2 .

Recommendation: There are no human factors data supporting the need for a minimum background luminance level when displaying light characters on a dark background.

Discussion: The ZH 1/618 standard recommends a minimum background luminance level in order to limit the extent of light or dark adaptations. Since the measurement of this background luminance is taken in the illuminated test condition, the requirement may likely be met by the reflected screen luminance, or by adjustment of the luminance control.

4.4.4 Luminance Contrast

Definition/Measurement: Contrast is defined as luminance modulation (M) by the following formula:

$$M = (L_{\max} - L_{\min}) / (L_{\max} + L_{\min})$$

$L_{\max}$ is the higher luminance of the background or the character, and $L_{\min}$ is the lower luminance of the two. Under the illuminated test condition, these values include the contribution from ambient light. These values are shown in Figure 2.

Values of M can be converted to other measures of contrast as follows:

$$\text{Contrast Ratio (CR)} = L_{\max}/L_{\min} = (1 + M) / (1 - M)$$

$$\text{Relative Contrast (C)} = (L_{\max} - L_{\min}) / L_{\min} = 2M / (1 - M)$$

Standard: The luminance modulation shall be adjustable. Minimum character luminance modulation shall be equal to or less than 0.5 (contrast ratio of 3:1) and shall be adjustable to at least 0.82 (contrast ratio of 10:1) while maintaining at least minimum values for resolution (subhead 4.4.1).

Discussion: A minimum contrast luminance modulation is necessary to ensure the legibility and readability of characters. Some standards (ZH 1/618 and DIN 66234) specify a maximum luminance modulation of 0.88 (contrast ratio of 15:1). There is no human factors data to support a limit on maximum contrast.

4.4.5 Color Contrast

Definition/Measurement: Color contrast is the degree to which colored symbols differ from their colored background. Color contrast is measured as defined in ANSI/HFS 100-1988.

Standard: For adequate legibility, colored symbols should differ from their colored backgrounds by a minimum of 100 delta E (CIE $Y_u'v'$) units.

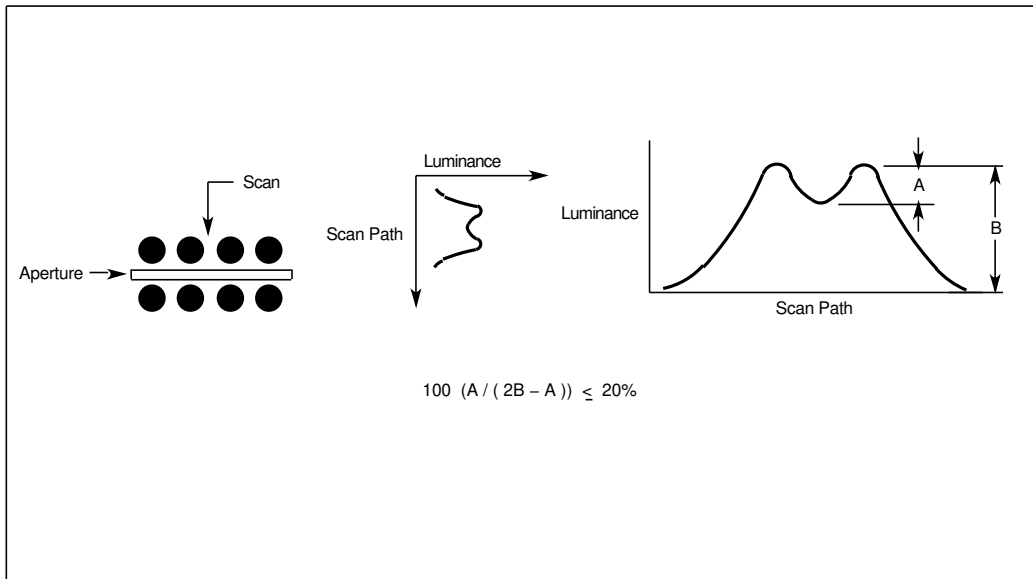
Recommendation: Pure blue on a dark background should be avoided for text, for thin lines, or for high resolution information. Simultaneous presentation of both pure red and pure blue (or to a lesser extent, red and green, or blue and green) on a dark background may result in chromostereopsis (a three-dimensional effect) and should be avoided unless this effect is acceptable or intentional.

Discussion: This is often controlled by the application software rather than the display unit.

4.4.6 Raster Modulation and Fill Factor

Definition/Measurement: Raster modulation is the luminance modulation in the direction perpendicular to adjacent raster lines on a CRT when all pixels are in their *on* state. Raster modulation is measured from a microphotometric scan as shown in Figure 6. These measurements are made in a dark environment.

Figure 6: Schematic of Measurement Technique and Method for Determining Percent Raster Modulation.



Fill factor is the percent active area of nonCRT displays. It is computed as:

$$\text{Fill Factor} = \frac{\text{Active Area of Pixel}}{\text{Total Pixel Area}}$$

Standard: For a CRT display having a pixel density of less than 30 pixels per degree (or 3.4 pixels/mm (87 pixels/inch)) at the design viewing distance of 500 mm (19.69 in), the raster modulation shall be equal to or less than 20%. For displays having a luminance control, this requirement is to be met when the pixel luminance is one half the maximum luminance.

For nonCRT displays having a pixel density of less than 30 pixels per degree at the design viewing distance (500 mm [19.69 in]), the fill factor shall be at least 44%. Higher fill factor values are preferable.

Discussion: A raster modulation greater than 20% (or a fill factor less than 44%) interferes with legibility of the displayed image because the raster structure (or space between pixels) becomes visible. Minimum raster modulation can be achieved by suitable spacing of adjacent lines, selection of the pixel size, or both. Maximum legibility is achieved with a *perceptual flat field* that is, one approaching zero raster modulation across adjacent lines or pixels.

Microphotometric Measurement: The effective width of the photometer should be no more than $\frac{1}{8}$ the width of a pixel. The length of a slit aperture should be at least 4 pixels.

4.4.7 Flicker

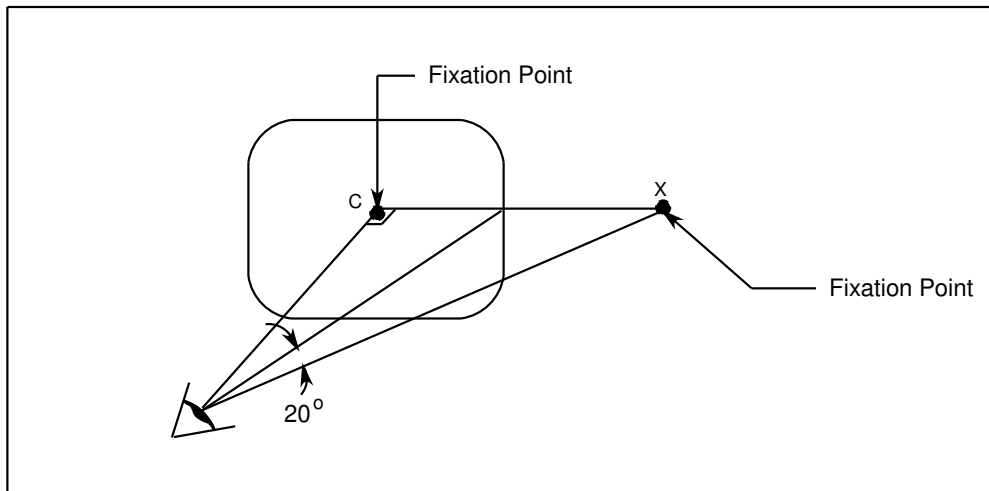
Definition/Measurement: Flicker is the perception of temporal variations in display luminance. The perception of flicker depends on the display luminance, phosphor persistence, the size and position of the screen in the visual field, and the age of the observer. There exist quantitative relationships that allow the perception of flicker to be predicted based on these variables. However, these relationships are still tentative and should at this time be used only to provide guidance in display design. Therefore, the measurement of flicker needs to be done with actual observers.

The following subjective test shall be performed to assess if the display under evaluation is perceived to flicker (adapted with modifications from ANSI/HFS 100-1988).

1. The display shall be set up in a dark environment.
2. Test subjects shall be dark-adapted 10 minutes prior to the test.
3. Twenty subjects shall be tested. At least 40% and no more than 60% shall be of the same sex. All subjects shall be between 18 and 35 years of age and be free from ocular pathology. All subjects shall pass optometric tests for vertical and lateral phoria, color normalcy, and near point acuity (20/30 or better with correction if needed).
4. The screen of the display shall be written with all pixels in the *on* state.
5. The viewing distance shall be 500 mm (19.69 in).
6. Subjects shall fixate individually on the two fixation points indicated in Figure 7 and perform the following test.
 - a. The display luminance shall be set as high as possible in excess of 45 cd/m² while still meeting the requirements of resolution, luminance contrast, and raster modulation.
 - b. Each subject shall fixate on each of the two fixation points as shown in Figure 7, for 15 seconds, following which the subject shall report whether or not the image appears to flicker.
 - c. If the subject does not perceive flicker, the test shall be terminated with a recorded response of *no flicker*.
 - d. If the subject perceives flicker, the display luminance will be reduced in a slow, continuous manner until the flicker ceases. This reduction in luminance shall be done while the subject is fixating at point *X* as shown in Figure 7. When the subject ceases to perceive flicker, he or she will then fixate on the center of the display and make another flicker judgment at this same luminance level. If the display does not flicker, the luminance at this value shall be measured and recorded.
 - e. The display luminance will then be reduced to a low level, well below that measured in subparagraph *d*. The luminance will then be increased in a slow continuous manner while the subject again fixates on point *X* until the subject again perceives flicker. At this luminance level, the subject will fixate at the center of the screen and make another flicker judgment. If the display still does not flicker, this luminance level will be measured and recorded.
 - f. Subparagraphs *d* and *e* will be repeated one more time each. The mean of the four recorded luminances shall be calculated. If the mean luminance exceeds 45 cd/m², the subject shall be classified as giving a *no flicker* response. If the mean

luminance is equal to or less than 45 cd/m^2 , the subject shall be classified as giving a flicker response.

Figure 7: Flicker Fixation Points



Standard: The display should be flicker free for at least 90% of the user population described under head 3.

Recommendation: The minimum refresh rate for the display of dark characters on a light background should be 72 Hz. This refresh rate is not guaranteed to eliminate the perception of flicker by 90% of all observers, but is a minimum to meet current marketing requirements.

Discussion: Currently, experiments are being performed at Digital that will help to define further the relationship between the variables involved in the perception of flicker from visual displays. These experiments are an attempt to replicate and extend the work of Farrell (1986). As these relationships become validated, they will be included as part of the standard.

NOTE

The flicker test described by TÜV is slightly different from the method described above. The TÜV procedure uses a total of three reviewers. The test is carried out for both negative and positive images. For this test, the display and viewing environment are set up as follows:

1. Adjust ambient light to generate 250 lux on the screen.
2. Fill screen with characters
3. Adjust character intensity to maximum allowed value. This requirement is open to subjective interpretation on the part of the representative from TÜV. For example, one interpretation of *maximum allowed value* is that both the contrast and luminance controls are set at their maximum positions. Another interpretation is that the controls are set as high as possible while still maintaining a *good* image (that is, no retrace lines are visible, and so forth).

Unfortunately, the document outlining the procedure for the flicker test is written so ambiguously as to allow for either interpretation.

4. Place the screen so that it is viewed from 500 mm (19.69 in). The fixation point of the viewer is such that the screen lies 30° in his or her peripheral field of view.
5. Judge the display then to be acceptable or not in terms of flicker.

4.4.8 Image Polarity

Definition: The display of light characters on a dark background is termed a *negative image* and the display of dark characters on a light background is termed a *positive image*.

Standard: The display shall be capable of displaying both positive and negative images. A user shall be able to select a preferred polarity. The display shall meet all the requirements of DEC STD 105 in either polarity.

Recommendation: Many users prefer positive image displays because this format resembles print on paper. Proper implementation of this format includes full overscan.

Discussion: The issue of positive versus negative contrast displays is largely one of preference and standards. There is little scientific evidence for the efficacy of one display format over the other.

4.4.9 Contrast (ZH 1/618 Definition/Requirements)

Definition/Measurement: The German definition of contrast requires that a full *on* character cell be placed in the center of the screen. The display shall be in the illuminated test condition described in subhead 2.4. A spot photometer is required to measure the luminance of the character cell and its background. The measuring aperture of the photometer must be positioned so that it covers 50% to 60% of the width of the character cell. After the luminance of the character cell is determined, the character cell is spaced out of the way, and the background luminance is measured.

The luminance is measured in both positive and negative display modes. For both conditions the following definitions apply:

L_c = intensity in cd/m^2 of the character cell

L_b = intensity in cd/m^2 of the background

Contrast is then defined as L_c/L_b .

Standard:

	Contrast	
	Permissible	Recommended
Negative polarity	3/1 to 15/1	6/1 to 10/1
Positive polarity	$\leq 1/3$	1/5

4.5 CHARACTER SIZE AND SPACING

The following subheads describe character parameters when they are presented in a character cell format. These requirements are for the default font or one character set designed to meet ZH 1/618 standard when the display is in an 80-column, 24-line mode.

4.5.1 Design Viewing Distance

Definition: The design viewing distance aids the display designer in selecting the appropriate size of the displayed characters. The actual distance which users select is a function of not only the size of the displayed characters but also of the person's ability to maintain nominal focus and alignment of the eyes.

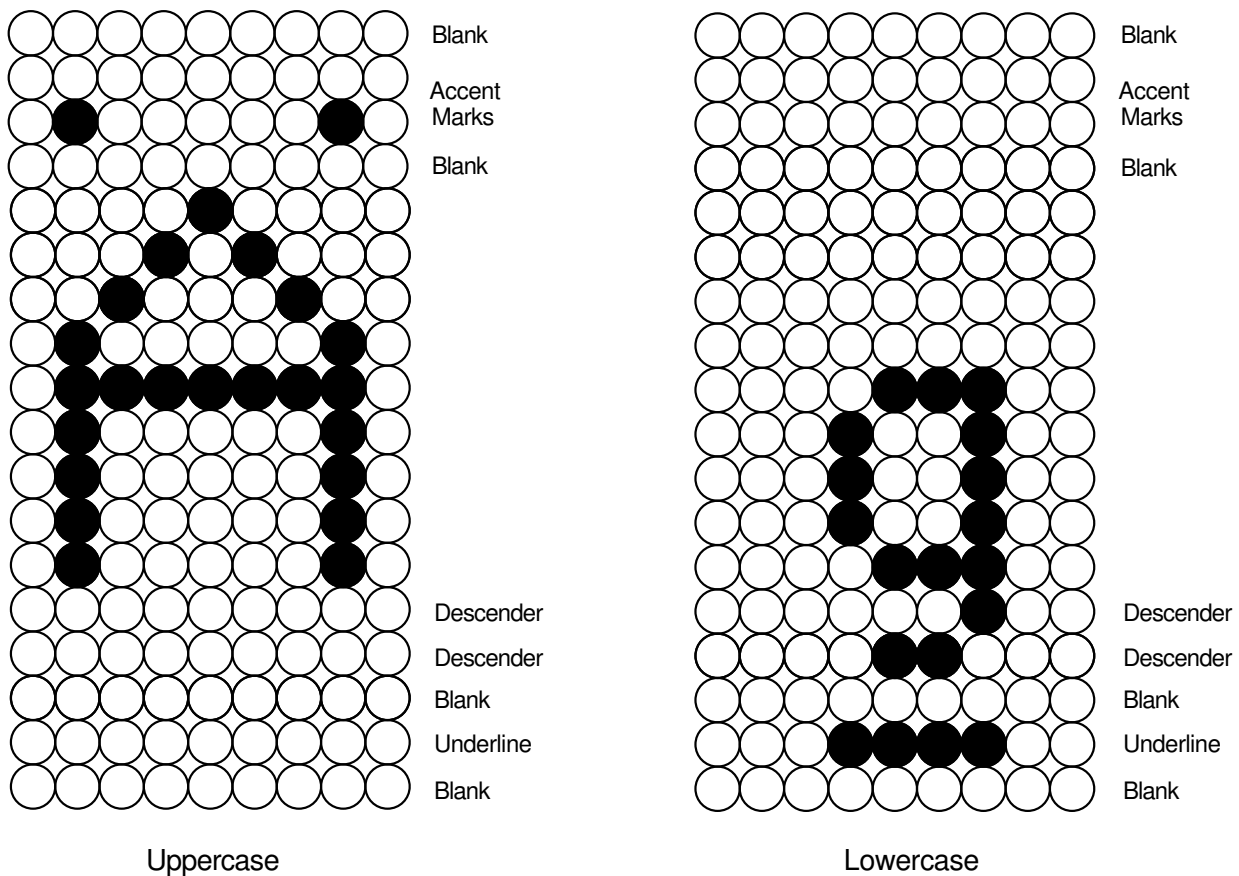
Standard: The design viewing distance is 500 mm (19.69 in). It is recognized, however, that actual working distances vary between about 335 mm (13.19 in) and 675 mm (26.57 in). The parameters for character size and spacing have been selected to account for this.

Discussion: The viewing distance requirement is based on alphabetic characters of Latin origin and Arabic numerals. If there is some special requirement to use a shorter distance than 500 mm (19.69 in), the design viewing distance should never be less than 300 mm (11.81 in).

4.5.2 Character Format

Definition: Character format is the width by height (in pixels) of the character matrix used for character formation. The definition of character format also includes the minimum size of the character cell. Pixel count measurement is performed visually with the aid of a 7x microscope.

Standard: The minimum character cell shall be 9 x 18 as shown in Figure 8. This size cell allows for the proper vertical and horizontal spacing between characters. The lowercase characters *p*, *q*, *g*, and *j* should be positioned within the cell as shown in Figure 8. For the purposes of this standard, a square pixel pitch (same spacing horizontally and vertically) is assumed.

Figure 8: Examples of Uppercase and Lowercase Characters

A 7 x 9 character matrix shall be the minimum matrix for tasks that require continuous reading for context, or when the legibility of the individual alphabetic character is important, such as in proofreading. Both uppercase and lowercase characters must be provided. The uppercase letter *I* is an exception to the minimum width requirement. The vertical height should be increased upward by two pixel positions if diacritical marks are used. For lowercase characters, the vertical height should be increased downward by at least two pixel positions to accommodate descenders of lowercase letters.

The character width of lowercase letters shall be at least four dot positions except the lowercase letters *f*, *i*, *j*, *l*, and *t*. The character width of the lowercase letters *m*, *w*, and *x* shall be at least five pixels.

NOTE

Special emphasis needs to be placed on making sure that there is proper spacing for ascenders and descenders. This spacing is especially important for languages other than English.

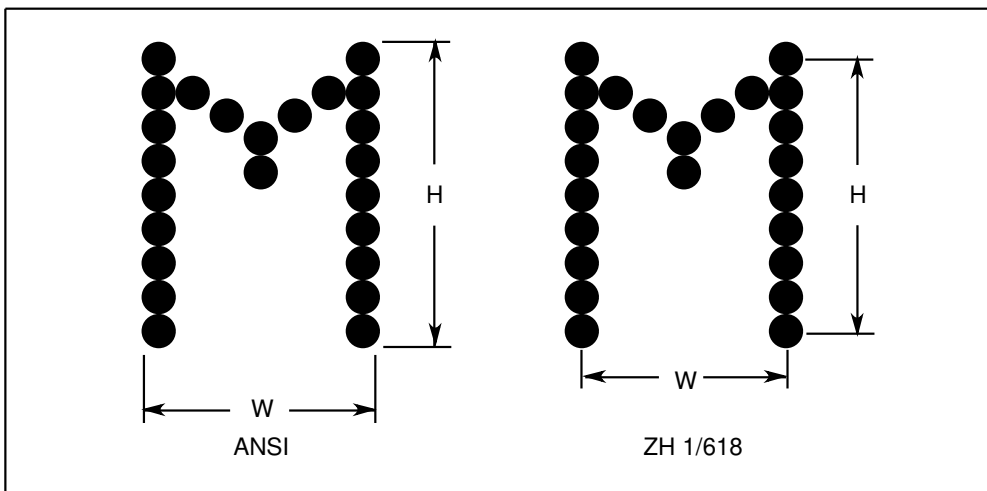
A 5 x 7 character matrix shall be the minimum matrix used for numeric and uppercase-only presentations such as captions for graphs. The vertical height should be increased upward by two pixel positions if diacritical marks are used.

A 4 x 5 character matrix shall be the minimum matrix used for superscripts and for numerators and denominators of fractions that are to be displayed in a single-character position. The 4 x 5 matrix may be used also for alphanumeric information not related to the user's task, such as copyright identification.

4.5.3 Character Height

Definition/Measurement: Character height is the vertical distance between the top and bottom edges of a nonaccented capital letter as defined in Figure 9. A 7x microscope equipped with a reticule is satisfactory for use in pixel count measurement. However, a microphotometer will provide a more objective and precise measurement. If a microphotometer is used, the edge of the character is defined as the 50% luminance point. The capital M shall serve as the measurement character. The German standard *ZH 1/618 Safety Rules for VDU Work Stations in Office Areas* requires the measurement to be pixel center to pixel center.

Figure 9: Height and Width of a Character



Standard:

Legibility: The minimum character height shall be 22 minutes of arc from the design viewing distance (3.2 mm [0.13 in] at the display surface) for tasks in which legibility is important. Characters should not be larger than 45 minutes of arc when groups of characters are displayed.

Readability: The minimum character height shall be 22 minutes of arc from the design viewing distance (3.2 mm [0.13 in] at the display surface) and the maximum character height shall be 24 minutes of arc (3.5 mm [0.14 in] at the display surface) for tasks in which readability is important.

Discussion: Legibility is the rapid identification of single characters that may be presented in a noncontextual format. Readability is the ability to recognize the form of a word or groups of words for contextual purposes.

4.5.4 Character Height-To-Width Ratio

Definition/Measurement: Character height is as previously defined. Character width is the horizontal distance between the right-most and left-most edges of a character as shown in Figure 9. Character width is measured using the same technique used to measure character height.

Standard: For fixed column formats, the height-to-width ratio shall be between 1:0.7 and 1:0.8. For display formats using more than 80 characters on a line, ratios as low as 1:0.5 are permitted.

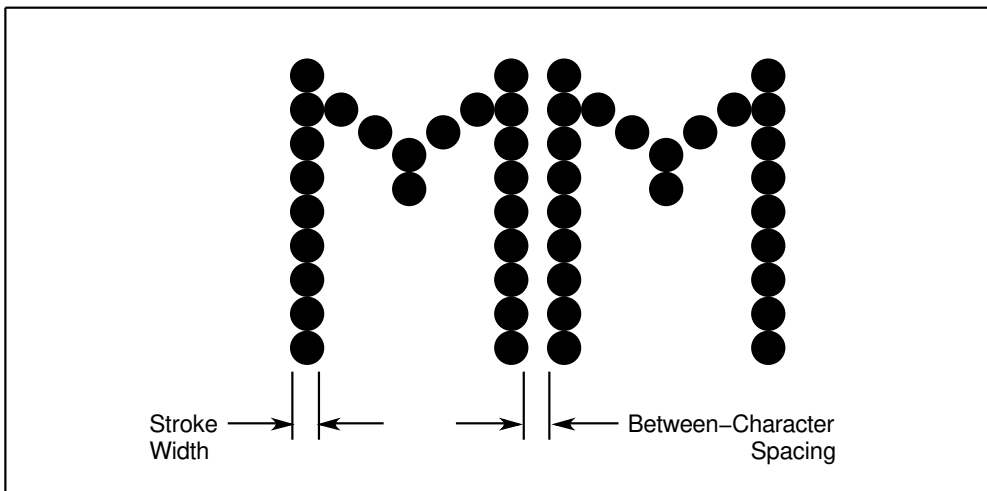
Recommendation: The character height-to-width ratio should be 1:0.7.

Discussion: The ANSI/HFS 100-1988 standard (6.15) elaborates: "Some letters...are customarily seen as narrower than others. For example, in a given character set, the letter I, and sometimes the letter J, appear narrower than M and W. Lowercase letters may similarly vary in width. Accordingly, the height-to-width ratio of a given character set should be the modal character width—that is, the width that occurs most often—in the set of capital letters."

4.5.5 Stroke Width

Definition/Measurement: Stroke width is the edge-to-edge width of a character stroke as shown in Figure 10. Stroke width is measured as shown in Figure 3 or with a 7x microscope. This requirement is for character cell displays only.

Figure 10: Definition of Stroke-Width and Between-Character Spacing



Standard: The stroke width shall be between 8.33% and 20% of the character height.

Discussion: The ANSI\HFS 100-1988 standard makes the following comment: "Once the character is well above the minimum size, contrast, and luminance level, the stroke width of a character is not critical for performance."

4.5.6 Between-Character Spacing

Definition/Measurement: This spacing is the horizontal distance between adjacent characters at their nearest point as shown in Figure 10. Measurement is made using one of the techniques described to measure character height and width.

Standard: The spacing between characters shall be such that alphanumeric characters do not touch. The spacing shall amount to at least one pixel or 15% of the character width in the horizontal direction or whichever is greater. See Figure 8.

Discussion: The Japanese Industrial Standard requires a minimum spacing of 20% of character height.

4.5.7 Between-Word Spacing

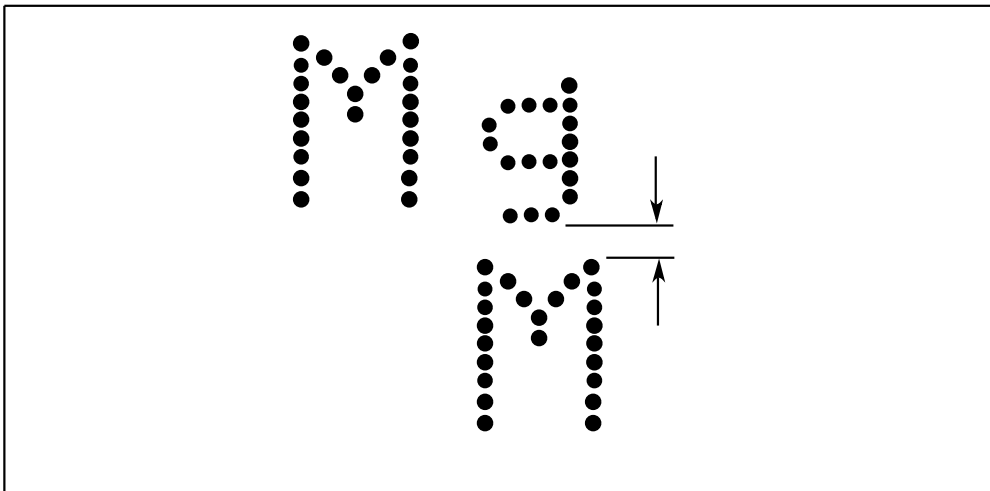
Definition/Measurement: This spacing is the horizontal distance between adjacent words at their nearest point. Measurement is made using the same technique described to measure character height and width.

Standard: A minimum of one character cell width shall be used between words. For proportional spacing, the capital *N* shall be used.

4.5.8 Between-Line Spacing

Definition/Measurement: This spacing is the distance between vertically adjacent characters at their nearest point as shown in Figure 11. Measurement is made using the same technique described to measure character height and width.

Figure 11: Between-Line Spacing



Standard: Between-line spacing shall be a minimum of two stroke widths or 15% of character height, whichever is greater. This space shall not be used for character ascenders, descenders, accent marks, underlines, subscripts, or superscripts.

Discussion: The ANSI\HFS 100-1988 standard comments that, in practice, between-line spacing (between vertically nonaccented capital letters) results in a space of between 50% and 100% of character height.

4.5.9 Font

Definition/Measurement: Font refers to the fundamental geometry or style of a particular set of alphanumerics. Measurement is by visual inspection.

Standard: The character design of the default font should be the same or geometrically as similar as possible to DIN 66009, Font B for Optical Character Recognition) as shown in Figure 12. Other fonts can be available as long as Font B is available.

Figure 12: Representation of Font B. (For exact style, see DIN 66 009.)

1 2 3 4 5 6 7 8 9 0
 A B C D E F G H I J K L M
 N O P Q R S T U V W X Y Z
 a b c d e f g h i j k l m
 n o p q r s t u v w x y z
 * + - = / . , : ; " ' ? !
 () < > % # & \$ | |
 ' Ä Ö Ü ß ä ö ü
 § ■ —

Nr 92

Serifs are allowed only if they increase the recognizability of characters.

All characters of a font set should have the same thickness. An exception to this may be made for the characters %, ,, ., :, and ' which are allowed to be thicker in order to increase their recognizability.

The cursor should be clearly distinguishable from all other characters.

The legibility of the display shall be such that a test subject can identify not less than 99% of the characters in the center and corners of the screen when the characters are in the subject's first language.

All characters in the character set shall be recognizable and distinguishable without possibility of confusion. The following sets of characters shall be distinguishable.

The number 0 and the letter O. The figure ø shall not be used as a number or as the letter O since it is a national letter.

The letters I and l, the number 1 and vertical bar |

The letters B, R, and β, and the number 8

The letters O, D, and Q

The letters q and g (even when underlined)

The letter S and the number 5

The letters X and K

The letters T and Y

The letters I and L

The letters U and V

The letters m and w

The letter G and the number 6

The letter Z and the number 2

The letters R and K

The letters C and G

Recommendation: Font B was designed for optical character recognition and not for maximum legibility/readability for humans. It should not, however, be the only font that is available.

4.5.10 Angle of View

Definition: The angle between the line-of-sight and the line orthogonal to the surface of the display at the point where the line-of-sight intersects the image surface of the display.

Standard: A display should be legible from any angle of view up to at least 40° from the normal to the surface of the display, measured in any plane. If this is not the case, the restricted angle of view shall be specified, and the display shall be easy to reposition to an orientation in which it is legible.

4.6 CODING OF DISPLAYED INFORMATION

4.6.1 Luminance Coding

Definition/Measurement: A distinction needs to be made concerning absolute intensity coding versus relative intensity coding. Absolute coding happens when luminance differences are used as one dimensional codes unsupported by adjacent information. Relative coding happens when luminance differences are used to discriminate between

either adjacent areas such as sections of a pie chart, or nonadjacent areas such as highlighted text. Luminance will be measured with a photometer when the display is in a dark environment.

Standard:

Absolute intensity coding — Only a restricted number of intensity levels should be used, none of which must be less than 20 cd/m². The number of levels used is dependent upon the maximum display luminance. In all cases, highlighted areas shall differ in luminance by at least 50%. For displays having a maximum luminance between 60 cd/m² and 100 cd/m², two levels can be used. For displays having a maximum luminance above 100 cd/m², a maximum of three levels shall be used. For displays with a maximum luminance of less than 60 cd/m², intensity coding shall not be used as the only dimension for absolute discrimination.

Relative intensity coding — Adjacent areas should have a luminance difference of at least 7%. Nonadjacent areas should have a luminance difference of at least 20%.

Discussion: The ANSI standard comments: "The use of different intensity levels to code information on a display must be approached with caution. A critical distinction must be made between absolute and relative luminance discrimination. Due to the insensitivity of the visual system for absolute luminance discrimination, only limited use should be made of luminance differences for coding."

4.6.2 Blink Coding

Definition: Blink coding is defined as temporally alternating the luminance of an object, a portion of an object, or the background as a means of conveying information to the operator.

Standard: No more than two different blink rates should be used. The difference between the two blink rates should be at least 2 Hz. The slow blink rate should be not less than 2 Hz and the fast blink rate should not be more than 5 Hz. The percentage of time that the image should be *on* should be greater than or equal to the time that it is *off*. A 50% duty cycle is preferred.

Blinking associated with cursors shall be independently suppressible.

Discussion: The International Organization for Standardization (ISO 9241-3) draft makes the distinction between blink coding used to attract attention and blink coding used where readability is required. For the former, the standard is the same as above. For the latter, a single blink rate of 1/3 to 1 Hz shall be used with a recommended duty cycle of 70%. If a large area, such as a full screen, is used for blink coding, the rate should be not more than 4 Hz.

4.6.3 Color Coding

Definition/Measurement: This type of coding is used for discriminability or conspicuousness of displayed information. Color coding is measured as described in ANSI/HFS 100-1988.

Standard: All colors in the set used for default color coding should differ from one another by a minimum of 40 delta *E* (CIE *L*u*v**) units. This approach will make available at least 7 to 10 simultaneous colors. Color measurements should be made under the presumed ambient lighting conditions in which the display will be used.

4.7 DISTORTIONS OF THE DISPLAYED IMAGE

4.7.1 Luminance Uniformity

Definition/Measurement: Luminance uniformity means that luminances that are supposed to be the same, appear the same. Uniformity can be measured with a microphotometer when the display is in a dark environment. Two categories of luminance uniformity are important for this standard. These are large-area and small-area uniformity.

Large-area uniformity is defined as the luminance difference between the center and each of the four corners as defined in Figure 4, relative to the luminance in the center. This ratio is computed for each of these positions using the following formula.

$$(\text{luminance } 1, 2, 3, \text{ or } 4) - (\text{luminance } 5) / (\text{luminance } 5)$$

Small-area uniformity is defined as luminance variations within a circle of diameter one-half of a degree of arc (4.35 mm [0.17 in] on the display surface, calculated from the design viewing distance) anywhere on the display, relative to the luminance at the center of the display. This ratio is computed using the following formula.

$$(\text{max luminance difference in circle}) / (\text{luminance } 5)$$

Standard: Both large and small Area uniformities shall be less than or equal to 0.5 as calculated with the formulae described above.

This requirement does not apply to anti-aliased fonts or to multicolor displays.

Discussion: There is limited human factors research that shows luminance uniformity has an impact on performance. However, keeping uniformity within the above limits will ensure that the subjective image quality of a display will not be degraded due to the perception of unintended luminance variations.

4.7.2 Color Uniformity

Definition: Color uniformity means colors that are supposed to be the same must appear the same.

Standard: For an intended uniform color appearance, the variation in color from the center of the display to the edge of any portion thereof shall not be greater than 5 delta E (CIE $L^*u^*v^*$) units. The technique for the computation of the color difference (delta E) is the same as described in the ANSI/HFS 100 standard.

4.7.3 Position-Related Distortions of Character Shape

Definition/Measurement: This distortion refers to the variation in height and width of any one character when displayed at different positions on the screen. The uppercase M will be displayed at the five screen locations shown in Figure 4. The height and width of each of the characters will be measured as defined in Figure 9. The following ratios then need to be computed.

$$\text{Height distortion} = \frac{H_{\text{max}} - H_{\text{min}}}{H_{\text{max}}} \times 100$$

$$\text{Width distortion} = \frac{W_{\max} - W_{\min}}{W_{\max}} \times 100$$

Where, $H_{\max}$ = greatest height,
 $H_{\min}$ = smallest height,
 $W_{\max}$ = greatest width,
 $W_{\min}$ = smallest width.

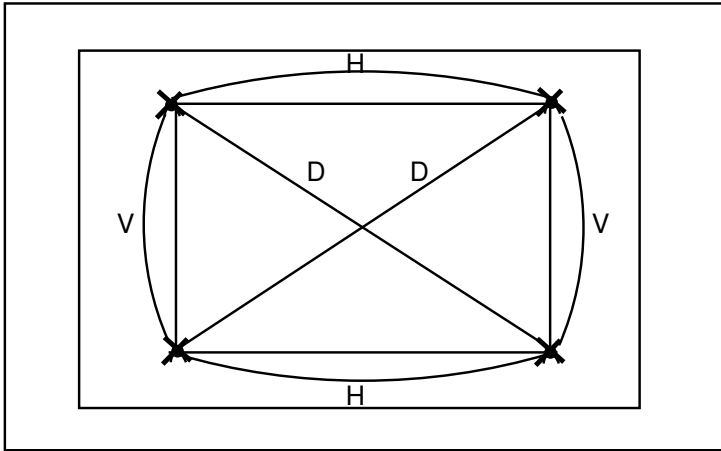
Standard: The height and width distortion should each be less than 10%.

Discussion: *Distortion* is the term used by the national and international standards when referring to the topic of variations in height and width of characters as a function of location. Display designers may refer to this same topic as *position-related nonlinearity of character shape*.

4.7.4 Image Orthogonality

Definition/Measurement: Orthogonality is the appearance of perpendicularity of rows and columns to each other. The corner positions of the main viewing area are filled with the capital letter X. The vertical, horizontal, and the diagonal distances are measured at the same point on each letter (the center point) and referenced as shown in Figure 13.

Figure 13: Screen Layout for the Measurement of Image Orthogonality



Standard: The value of the following ratio shall be met.

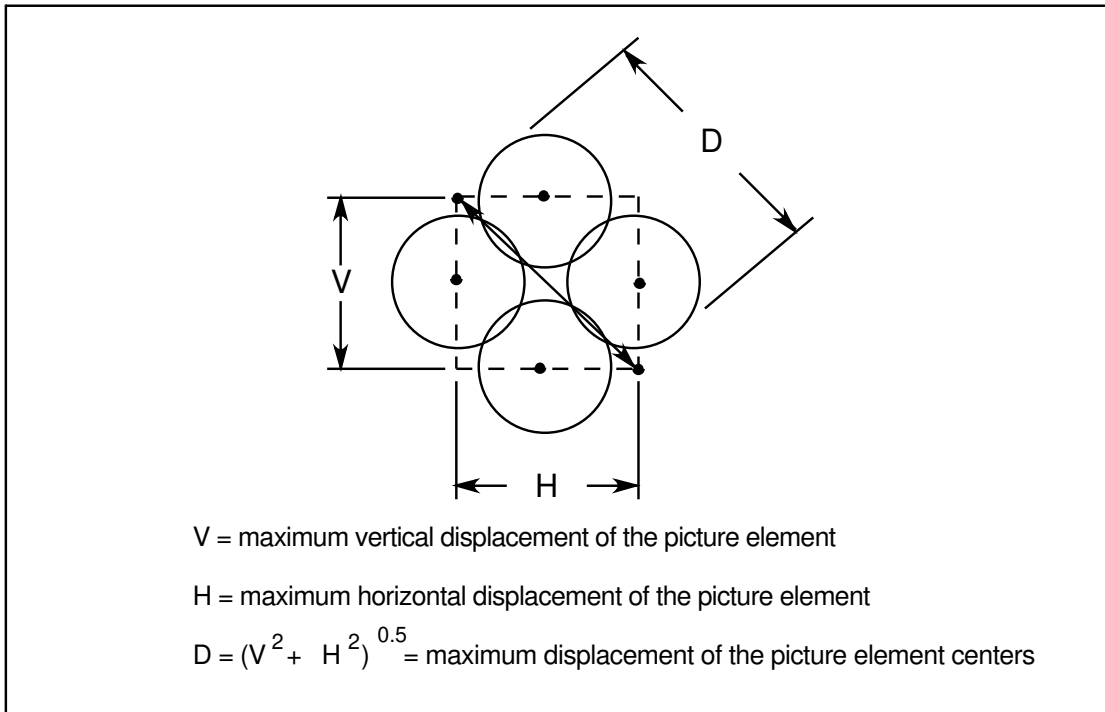
The ratio of the difference between the longer and shorter diagonals D and their mean length shall not exceed 0.04 times the ratio of the mean length of the shorter (vertical or horizontal) edges to the mean length of the longer (horizontal or vertical) edges.

$$\frac{D_M - D_m}{\left(\frac{D_M + D_m}{2}\right)} \leq 0.04 \frac{\min \left\{ \frac{V_M + V_m}{2}, \frac{H_M + H_m}{2} \right\}}{\max \left\{ \frac{V_M + V_m}{2}, \frac{H_M + H_m}{2} \right\}} \quad \text{Where: } M = \text{Max and } m = \text{min.}$$

4.7.5 Geometric Stability (Jitter)

Definition/Measurement: Jitter is the variation in the geometric location of a picture element over time. The measure of jitter is the calculated maximum diagonal of the rectangular figure that minimally encloses the center points of the picture elements as shown in Figure 14. The measurement of jitter is defined as D in this figure. Currently, there is no accepted technique by which jitter can be measured.

Figure 14: Measurement of Jitter



Standard: Variations in the geometric location of a picture element shall be equal to or less than 0.0002 mm per mm of viewing distance over a period of one second. From Figure 14 this may be expressed as

$$\text{Viewing Distance} \times 0.0002 > (H^2 + V^2)^{0.5}.$$

Discussion: The above standard only specifies the maximum amplitude of jitter. A complete definition of jitter would include not only amplitude but waveform and frequency as well.

Very low frequency motion (period of 1 minute or more) may be purposely designed into displays to reduce phosphor fatigue.

4.7.6 Image Linearity

Definition/Measurement: Image linearity as defined in this standard consists of two parts, linearity and deviations in the positioning of symbols on the display. Linearity is defined as the deviation of a straight line from its exact form, expressed as a percentage of the total length of the line. The symbol positioning deviation is defined as the deviation of any element of a pattern, such as characters within a word from their exact location, expressed as a percentage of the dimensions of the total pattern. Measurement of symbol positioning is, at this time, performed by placing a transparent, calibrated grid template on the screen surface.

Standard: Nonlinearity of any column or row shall not be more than 1% of the length of the column or row respectively.

This value is computed as the following ratios.

The ratio of the difference between the longer and shorter horizontal edges of a row (H) and their mean length shall not exceed 0.01.

The ratio of the difference between the longer and shorter vertical edges of a column (V) and their mean length shall not exceed 0.01.

Also, the horizontal displacement of a symbol position relative to symbol positions directly above and below the symbol position shall not vary by more than 5% of the symbol box height. The vertical displacement of a symbol position, relative to the symbol positions to the right and left of the symbol position, shall not vary by more than 5% of the symbol box height. The symbol box is the height and width of the character as shown in Figure 9.

Discussion: The ANSI/HFS 100-1988 standard comments, "The purpose of the requirements for registration accuracy of adjacent symbol positions is to prevent apparent symbol position irregularities that may be a source of interference to the reading process. The purpose of the column and row linearity recommendations is to provide the perception of parallel columns and parallel rows."

4.8 VISUAL DISPLAY HOUSING SURFACES

4.8.1 Reflectivity

Definition/Measurement: Reflectivity is measured as the reflectance factor using a spectrophotometer. The reflectance factor is simply the ratio of the flux reflected from a specimen for specified geometric and spectral conditions of radiation and view to that reflected from a perfect diffuse reflector under the same conditions. The geometric and spectral conditions are those specified by the American Society for Testing and Materials (*ASTM E 97-82 Standard Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry* and *ASTM E 179-88 Standard Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials*). These conditions are 45° illumination, 0° viewing (measurement) under CIE standard illuminant C. (CIE illuminant D65 is used by the German testing organization (TÜV).) When these measurement conditions are obtained, the reflectance factor is read from the spectrophotometer as the tristimulus value Y .

Standard: The reflection factor of the display bezel surfaces shall be between 20% and 75%. Values between 20% and 50% are recommended. An actual sample of the material as it will be produced for the product (textured finish plus color) needs to be measured.

Discussion: The above standard comes from European and Australian standards. The intent of this standard is to avoid excessive contrast between the display screen, bezel, and source material in order to minimize the eye's need to adapt when scanning between these areas. However, there are limited human factors data to support these specific minimum and maximum values. This measurement can be taken within Digital by Materials Research.

4.8.2 Gloss

Definition/Measurement: Gloss is the specular reflectance of the surface finish of the display equipment enclosures. It can be measured using a 60° gloss instrument.

Standard: The specular reflectance, or gloss, of all surfaces shall be 45% or less.

Discussion: See *DEC STD 092-3 Finish and Color Standard: Finish Material Test Requirements*.

5 KEYBOARDS

Keyboards must be designed to accommodate a wide range of user sizes, postural adjustments during prolonged use, and a variety of installations.

Comment: Special-purpose systems, such as portables, briefcase models, industrial applications, and the like, are to be handled as individual cases. This standard can be waived by the Ergonomics Domain Manager who is responsible for this standard.

Recommendation: Keyboard layout legends should be designed for the user applications to be resident on the system that the keyboard operates. Universal keyboards for diverse uses can compromise the user excessively. See *DEC STD 107-1 Digital Standard for Terminal Keyboards - Registry of Graphic Character Sets* and *DEC STD 107-2 Digital Standard for Terminal Keyboards - LK201 Character Sets and LK250 Character Sets*.

5.1 ADJUSTABILITY

Standard: Keyboards must be detachable from the display or other housing, and may be connected electrically by a flexible cord, or optically by an infrared transceiver, or by other means.

Recommendation: Incorporate a feature, such as rubber feet, to reduce sliding on work surfaces.

5.2 PROFILE

5.2.1 Height and Palm Rest

Standard: The height of the keyboard must be able to meet the 3.0 cm (1.18 in.) requirement of Germany, measured from the work surface to the highest point at the middle of the key cap surface at the home row (ASDF... row on USA typewriters). The slope of the keyboard must also be user adjustable for comfortable, error-free typing, to about 15° up. Keyboards that do not meet the 3.0 cm (1.18 in) requirement must be designed with a palm or heel-of-hand rest extending 5.0 cm to 10.0 cm (2 in to 4 in) in front of the space bar.

Recommendation: The width of the palm rest shall be about as wide as the keyboard layout and at approximately the height and slope angle of the keyboard.

NOTE

Low profile keyboards on standard U.S. typing stands may need to be elevated so that the typist's forearm is at least horizontal.

5.2.2 Slope

Standard: The key layout shall slope up and away from the operator at an angle of no more than 15° from the horizontal. See subhead 5.2.1.

Recommendation: Recommended minimum slope is 5°.

5.3 KEY SURFACE

5.3.1 Reflectivity

Definition/Measurement: Reflectivity is measured as the reflectance factor using a spectrophotometer. See subhead 4.8.1.

Standard: The reflectance factor of the visible key surfaces shall be between 20% and 75%. Values between 20% and 50% are recommended. An actual sample of the material as it will be produced for the product (textured finish plus color) needs to be measured.

Discussion: Key surfaces shall be designed to reduce distractions to the eye arising from surface reflections, glare, and the variety of lighting levels.

5.3.2 Gloss

Definition/Measurement: Gloss is defined as the specular reflectance of the surface finish of the keyboard housing surfaces. It can be measured using a 60° gloss instrument.

Standard: The specular reflectance, or gloss of all surfaces shall be 45% or less.

Discussion See *DEC STD 092-3 Finish and Color Standard: Finish Material Test Requirements*.

5.4 KEYBOARD HOUSING SURFACES

5.4.1 Reflectivity

Definition/Measurement: Reflectivity is measured as the reflectance factor using a spectrophotometer. See subhead 2.8.1.

Standard: The reflectance factor of the visible keyboard housing surfaces shall be between 20% and 75%. Values between 20% and 50% are recommended. An actual sample of the material as it will be produced for the product (textured finish plus color) needs to be measured.

Discussion Keyboard housing surfaces shall be designed to reduce distractions to the eye arising from surface reflections, glare, and the variety of lighting levels.

5.4.2 Gloss

Definition/Measurement: Gloss is defined as the specular reflectance of the surface finish of the keyboard housing surfaces. It can be measured using a 60° gloss instrument.

Standard: The specular reflectance, or gloss, of all surfaces shall be 45% or less.

Discussion: See *DEC STD 092-3 Finish and Color Standard - Finish Material Test Requirements*.

6 DOCUMENT HOLDER

6.1 ADJUSTABILITY

Standard: Document holders shall be adjustable in inclination from at least 15° from vertical to at least 75°.

Recommendation: Both vertical and horizontal flexibility in the plane of the operator are recommended. The design should be of sufficient strength to hold various size documents and provide for some degree of document handling: for example, correcting and initialing.

Comment: If designed as an accessory or part of the terminal, document holders should provide for a wide range of user sizes, postural adjustments during prolonged use, and a variety of installations (such as either side of the workstation) and sizes and weights of documents.

6.2 SIZE

Standard: Document holders shall accommodate documents of at least 21.59 cm wide by 27.94 cm high (8½ in by 11 in) for North American markets only, at least 21 cm wide by 29.7 cm high (8.27 in by 11.69 in) (A4 size) for markets outside North America only, and shall accommodate both sizes if intended for both markets.

NOTE

Legal-size paper in North America is 21.59 cm by 35.56 cm (8½ in by 14 in).

Recommendation: It is recommended that document holders also be designed for computer printouts (38.1 cm by 27.94 cm [15 in by 11 in] or 21.59 cm by 30.98 cm [8½ in by 12 in.]) or European DIN/ISO A4 size 21.0 cm by 29.7 cm (8.27 in by 11.69 in) where applicable, and that they be strong enough to hold a book or bulky report.

NOTE

Task lighting on the document should also be considered.

6.3 PLACEMENT

Standard: The design must allow the document holder to be placed at the same viewing distance from the operator as the screen and keyboard, and within 20° of the operator's line-of-sight to the screen and keyboard, to minimize head movements.

Comment: Document holders must be placed so that they reduce distractions to the eye arising from adjustments to various viewing distances, so that head movements are minimized.

6.4 DOCUMENT HOLDER SURFACE

6.4.1 Reflectivity

Definition/Measurement: Reflectivity is measured as the reflectance factor using a spectrophotometer. See subhead 2.8.1.

Standard: The reflectance factor of the visible surfaces of the document holder shall be between 20% and 75%. Values between 20% and 50% are recommended. An actual sample of the material as it will be produced for the product (textured finish plus color) needs to be measured.

Discussion: Document holder surfaces shall be designed to reduce distractions to the eye arising from surface reflections, glare, and the variety of lighting levels.

6.4.2 Gloss

Definition/Measurement: Gloss is defined as the specular reflectance of the surface finish of the document holder surfaces. It can be measured using a 60° gloss instrument.

Standard: The specular reflectance, or gloss of all surfaces shall be 45% or less.

Discussion: See *DEC STD 092-3 Finish and Color Standard: Finish Material Test Requirements*.

7 WORKSTATION

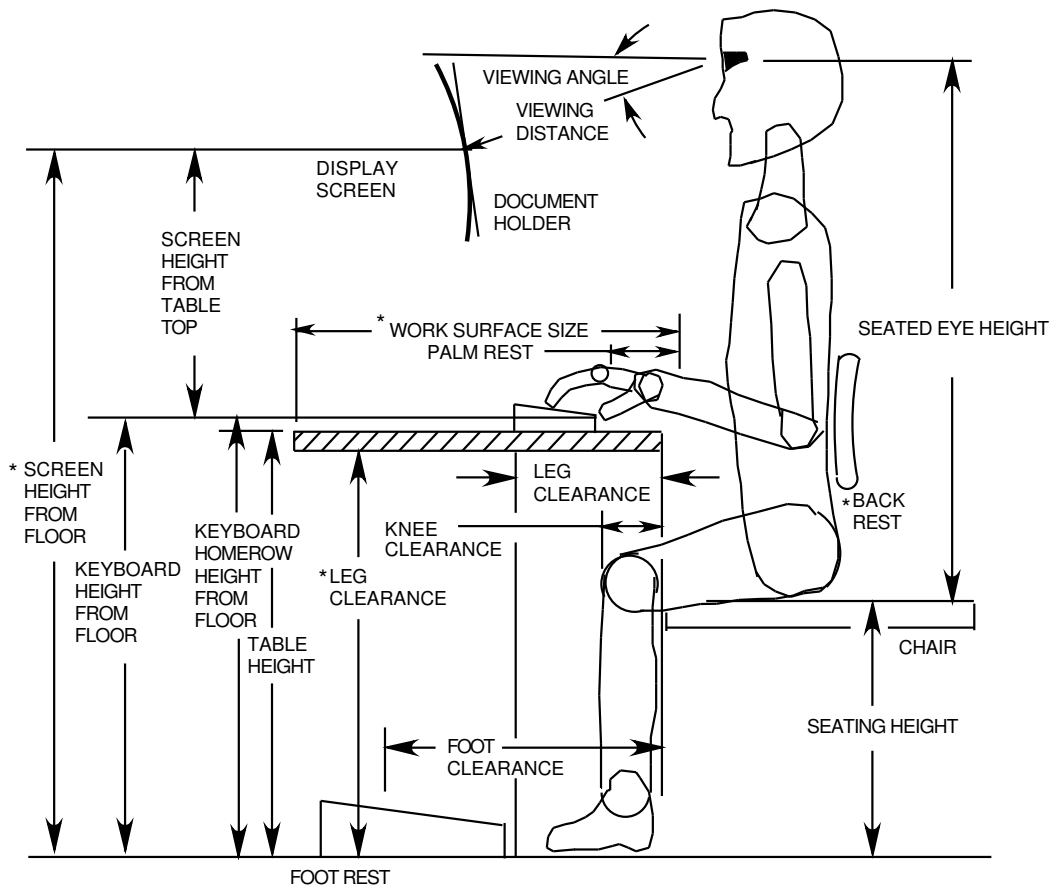
A workstation is defined as the work surface and the surrounding area used to support a display and a keyboard.

7.1 DIMENSIONS

Comment: To provide for a wide range of user sizes, postural adjustments during prolonged use, and a variety of installations, workstations should be adjustable. Standards differ slightly in assigned dimensions. Some variations are acceptable, although Germany's is the most stringent. Table 2 lists standard workstation dimensions. Refer to Figure 15.

Table 2: Standard Workstation Dimensions

Feature	Centimeters	Inches
Desktop height:		
Fixed	72.0 $\pm$ 1.0	28.4 $\pm$ 0.4 (typically higher in U.S.A.)
Adjustable	67.0 to 77.0	26.4 to 30.3
Desktop width, minimum	58.0	22.8
Typing Stand height	66.0 to 68.5	26.0 to 27.0
Leg/knee room:		
Fixed height, minimum	65.0	25.6
Adjustable height, minimum	62.0	24.6
Width, minimum	58.0	22.8
Depth at knees, minimum	45.0	17.7
Depth at feet, minimum	60.0	23.6
Footrest:		
Height		
Fixed front edge	4.0 $\pm$ 0.5	1.6 $\pm$ 0.2
Fixed rear edge, minimum	10.0	4.0
Adjustable front edge, minimum	3.5	1.4
Slope	0° to 20°	0° to 20°
Width, minimum	35.0	13.8
Depth, minimum	45.0	17.7

Figure 15: Standard Workstation Design Parameters

* Not specified in this standard.

7.2 SAFETY

Recommendations: To protect users from discomfort or injury, workstations shall be designed so that edges, covers, and protruding parts shall be rounded and have nonabrasive surfaces. All edges of the work surfaces should be dulled and avoid sharp corners. The minimum radius should be 2 mm on edges and 3 mm on corners. Users should be protected from heat and electric shock. Materials of high ignition temperature and slow fire growth shall be used. See *DEC STD 119-1 Digital Product Safety: Design Criteria*.

7.3 WORKSTATION SURFACE

7.3.1 Reflectivity

Definition/Measurement: Reflectivity is measured as the reflectance factor using a spectrophotometer. See subhead 2.8.1.

Standard: The reflection factor of the visible surfaces of the workstation shall be between 20% and 75%. Values between 20% and 50% are recommended. An actual sample of the material as it will be produced for the product (textured finish plus color) needs to be measured.

Discussion: Workstation surfaces shall be designed to reduce distractions to the eye arising from surface reflections, glare, and the variety of lighting levels.

7.3.2 Gloss

Definition/Measurement: Gloss is defined as the specular reflectance of the surface finish of the workstation. It can be measured using a 60° gloss instrument.

Standard: The specular reflectance, or gloss of all surfaces shall be 45% or less.

Discussion: See *DEC STD 092-3 Finish and Color Standard: Finish Material Test Requirements*.

8 OTHER PARAMETERS

8.1 WEIGHT LIMITS

Table 3 provides guidelines for the maximum weights that an ordinary person, and a trained materials handler, are capable of lifting. The weights indicated are per person for lifting, and they do not apply to such activities as rolling a system on a floor or down a ramp.

Table 3: Guidelines for Maximum Weight Limits

Weight Class	Ordinary Person	Trained Materials Handler
Transportable (lift and carry a significant distance)	8.2 to 9.1 kg (18 to 20 lbs)	—
Carriable	12.7 to 13.6 kg (28 to 30 lbs)	15.9 kg (35 lbs)
Maximum	—	22.7 to 27.2 kg (50 to 60 lbs)

Comment: As depicted in Table 3, the guideline for weight limits is divided into three weight classes: transportable (lift and carry a significant distance), carriable, and maximum permissible. This guideline is based on two classes of individuals: an ordinary person, and a trained, practiced materials handler. It is important to note that good hand-holds must be provided. If a product weighs more than 13.6 kg (30 lb), and must be removed from a carton, instructions recommending the use of two people should be provided. No limits have been established for portable (hand-held) products.

Perspective: These determinations have been obtained from studies that measured the lifter's physical strength and asked various lifters to rate the weights.

References: C. Abernethy, Memorandum: *Weight, User Classes of*, from Weight and Surface Temperature, Digital Technical Report 170, June 1982.

C. Abernethy and K. Akagi, LA12 Terminal Portability Report, Digital Technical Report 156, February 1981.

8.2 THERMAL ENVIRONMENT

8.2.1 Surface Temperature

Definition: This standard is concerned only with the temperature of external and internal surfaces which are intended to be touched during normal operation.

Standard: Surfaces that are intended to be touched during normal operation should not exceed 35°C (95°F) assuming an ambient temperature of 20°C (68°F). External surfaces that can be touched during operation should not exceed 50°C (122°F).

Discussion: See *DEC STD 120-0 Product Thermal Design Standard: Design Requirements* for measurement requirements. It is important to note that the surface temperature requirements listed in DEC STD 105-0 give maximum surface temperatures for the comfortable and safe operation by a user as opposed to the thermal requirements from a materials standpoint. Also, see DEC STD 119-0 for safety-based limits. Note that, again, safety limits are much higher than human comfort ranges.

8.2.2 Forced Air Exhaust

Definition: This standard is concerned with the air exhausted from the display and associated components.

Standard: Forced air exhausted from the display and associated components shall not be directed towards the position of the display operator or towards the position of adjacent workers.

Recommendation: If possible, a fan should not be used to provide airflow, as fans increase the noise of the display and may cause problems with air intake and exhaust.

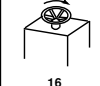
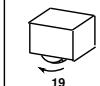
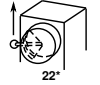
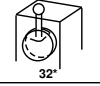
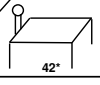
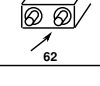
Discussion: All possible placements and configurations of the display or associated systems unit should be considered to ensure that forced air is not directed towards workers.

9 CONTROLS, INDICATORS, AND LABELS

9.1 COMMON CONTROL ACTION STEREOTYPES

Recommendations: Figure 16 is from IEC Publication 447 *Standard Directions of Movement for Actuators which Control the Operation of Electrical Apparatus*. The arrows indicate the direction the control should be moved to cause an increase in a physical quantity (voltage, luminous intensity, and so forth); to cause a change of condition (put into service, start, close an electric circuit); to define motion in relation to the operator. The operator is considered to be in the place of the number at the bottom center of each block in the figure.

Figure 16: Examples of Directions of Movements for Some Types of Actuators

Rotation										
Verical motion										
Horizontal motion	Right-left									
	Forward-backward									
Combination of differnt directions										
Set of atcuators										

9.2 CONTROL DESIGN PARAMETERS

Table 4 presents recommendations for four of the usual switch technologies.

Recommendations:

Table 4: Recommended Size and Force for Four Switch Types

Switches	Push Button	Knob	Lever	Crank ¹
Length and Width				
Minimum	1.27 cm (0.5 in)	2.54 cm (1.0 in)	1.27 cm (0.5 in)	
Maximum		10.16 cm (4.0 in)	7.62 cm (3.0 in)	

¹Essentially for one-handed operation, as opposed to finger control or switch operation.

Table 4 (Cont.): Recommended Size and Force for Four Switch Types

Switches	Push Button	Knob	Lever	Crank ¹
Length and Width				
Diameter	1.27 cm (0.5 in)			
Depth				
Minimum	1.27 cm (0.5 in)		7.62 cm (3.0 in)	
Maximum	7.62 cm (3.0 in)			
Displacement				
Minimum	0.32 cm (0.125 in)			
Maximum	3.81 cm (1.5 in)			
Resistance				
Minimum	0.14 N	0.17 N	0.17 N	0.44 N
Maximum	0.56 N	0.56 N	0.44 N	2.22 N
Recommended	0.14 N	0.17 N	0.17 N	1.11 N

¹Essentially for one-handed operation, as opposed to finger control or switch operation.

Comment: The data in this table recommends certain size(s) and force(s) for four common controls.

Reference: H.P. Van Cott, and R.G. Kinkade, *Human Engineering Guide to Equipment Design*, Joint Army-Navy-Air Force Steering Committee, American Institutes for Research, Washington D.C., 1972, pp. 360, 368, and 370.

9.3 COLORS OF CONTROLS AND INDICATORS

The following material constitutes the sole existing standard in the area of design of controls, labels, and indicators—IEC 73. This standard was developed for electrical (not necessarily electronic) equipment, and for an era of filament lamps with colored, transluminant coverings. It is included here, as a point of departure in selecting colors for indicators, because the general categories described are still relevant—although their interpretation for a specific computer device may vary. The examples and meanings obviously are neither especially computer-relevant, nor relevant to new technologies, such as LEDs.

When a design question arises regarding controls, labels, and indicators, and more information is required, contact the manager of the Corporate Human Factors Engineering Department.

The following is from the text of *IEC 73 Colours of Indicator Lights and Push-buttons*.

9.3.1 Colors of Push Buttons

NOTE

Subhead 9.3.1, subhead 9.5, and subhead 9.6.2 are compatible with the corresponding clauses of IEC Publication 73 (third edition, 1984): *Colours of Indicator Lights and Push-buttons*.

9.3.1.1 STOP, OFF, and Emergency Buttons

The color RED shall be used for STOP, OFF or emergency buttons only. STOP, OFF and emergency buttons shall be RED.

The color RED is reserved for the function STOP or to cause the opening of a main circuit, that is, when a red push button is actuated, this shall cause the equipment to stop, to be de-energized, to initiate a fire alarm, and so forth.

9.3.1.2 START or ON Buttons

The preferred color of START buttons or ON buttons (which cause the closing of switching devices) is GREEN, but the neutral colors BLACK, WHITE, or GRAY are permitted.

9.3.1.3 The Same Button Serving for START and STOP or ON and OFF

- Push buttons that act alternately as START and STOP or ON and OFF buttons when pressed several times , shall be BLACK, WHITE or GRAY. Neither RED nor GREEN shall be used.
- Push buttons that cause a movement while they are pressed and stop the movement when they are released (such as inching or jogging push buttons) shall be BLACK, WHITE, GRAY or GREEN with a preference for BLACK. Such push buttons shall not be RED.

9.3.1.4 RESET Push Buttons

RESET push buttons (used, for example, with protective relays) shall be BLUE, BLACK, WHITE or GRAY, except RESET push buttons that also act as STOP or OFF push buttons, which shall be RED.

9.3.1.5 Recommended or Compulsory Applications of Colors for Push Buttons

The recommended applications of colors for push buttons are shown in Table 5. Some of the requirements under subhead 9.3.1.1 through subhead 9.3.1.4 are also included in Table 5.

Table 5: Colors of Push Buttons and Their Meanings

Color ¹ (1)	Meaning of Color (2)	Typical Applications (3)
Red	Action in case of emergency	- Emergency stop - Firefighting
	STOP	- General stop

¹ It is recommended that other colors, as for example orange or brown, not be used in order to have a clear distinction between different colors.

Table 5 (Cont.): Colors of Push Buttons and Their Meanings

Color ¹ (1)	Meaning of Color (2)	Typical Applications (3)
	OFF	- To stop one or more motors - To stop a part of a machine or - To stop the cycle (if the operator pushes the button during a cycle, the machine stops after the relevant cycle is completed) - To open a switching device - Reset combined with STOP
Yellow or amber	Intervention	Intervention to suppress abnormal conditions or to avoid unwanted changes.
Green	START ²	- General start - To start one or more motors
	ON	- To start a part of a machine or - To close a switching device
Blue	Any specific meaning not covered by the above colors	A meaning not covered by the colors red, yellow, and green, can be allocated to this color in particular cases.
Black, grey, white	No specific meaning assigned	May be used for any function except for buttons with the sole function of STOP or OFF.

¹It is recommended that other colors, as for example orange or brown, not be used in order to have a clear distinction between different colors.

²If, according to text under subhead 9.3.1.2, GREEN and BLACK are used for START or ON, it is recommended to use GREEN for preparatory functions and BLACK for execution.

9.4 MARKING SYMBOLS

For marking symbology, refer to *DEC STD 178-5 Marking Symbology*.

9.5 INDICATOR LIGHTS (SIGNALLING LAMPS)

9.5.1 Colors of Indicator Lights

Where used for indicator lights, the three colors RED, YELLOW, and GREEN shall have the meanings assigned to them in column (2) of Table 6. These three colors shall not be used with any other meaning. For other purposes, BLUE or WHITE indicator lights shall be used, as shown in Table 6.

Table 6: Colors of Indicator Lights and Their Meanings

Color (1)	Meaning of the Lighted Indicator (2)	Explanation (3)	Typical Applications (4)
Red 620 nm and above*	Danger or alarm	Warning of potential danger or a situation that requires immediate (corrective) action.	- Failure of pressure in lubricating system - Temperature outside specified (safe) limits - Danger from accessible live or moving parts
Yellow or amber 580 - 590 nm*	Caution (or Write protect)	Change or impending change of conditions	- Temperature (or pressure) different from normal level - Overload, the duration of which is permitted for limited time only
Green 500 - 560 nm*	Safety	Indication of a safe condition or Authorization to proceed, clear way	- Cooling liquid circulating - Automatic boiler control in operation - Machine ready for operation
Blue 420 - 290 nm*	Specific meaning assigned according to the need in the case considered	Blue may be given any specific meaning that is not covered by the three colors: Red, Yellow, and Green	- Indication of remote control - Selector switch in "set up" position
White	No specific meaning assigned (neutral)	Any meaning may be used whenever doubt exists about the application of the three colors: Red, Yellow and Green, as for example, for confirmation	

*Peak wavelength is ± 5 nm.

Comment: Presently, only red, yellow, white, and green LEDs are available. Blue must be very bright to be seen, and its use should be avoided.

9.5.2 Flashing Lights

For further distinction or information and especially to give additional emphasis, flashing lights may be used, for example, for the following purposes.

- To attract further attention.
- To request immediate action.

- To indicate a discrepancy between a commanded state and the actual state of the related equipment.
- To indicate a change in progress (flashing during a transition period) and so forth.

For flashing lights, the colors chosen and any instruction legend that may be given will determine if an action, for example by the operator, is necessary.

Two flashing rates, $f1$ and $f2$, are recognized (see below). The information with the highest priority shall be associated with the highest flashing rate used in the case concerned.

The permitted ranges for flashing frequencies are the following:

- $f1$: slow flashing, 0.4 Hz to 0.8 Hz (24 to 48 flashes per minute)
- $f2$: 1.4 Hz to 2.8 Hz (84 to 168 flashes per minute)

Where only one flashing rate is used, the rate shall be $f2$.

The ratio $f1:f2$ of the flashing frequencies shall be at least 1:2.5 but not more than 1:5. A ratio of 1:4 is recommended (for example the frequencies 0.5 Hz and 2 Hz).

It is recommended that the *pulse/pause* ratio be about 1:1, that is, the ON time of the light should be about equal to the OFF time. For $f1$, the *pulse* may be longer than the *pause*; for $f2$, the *pulse* may be shorter than the *pause*. However, for $f1$ the *pulse/pause* ratio of 2:1 and, for $f2$, the *pulse/pause* ratio of 1:2 shall never be exceeded.

9.6 ILLUMINATED PUSH BUTTONS

9.6.1 General

The illuminated push buttons considered here are those which:

- Show only one and the same color whether lighted or not
- Return to their rest position by themselves when released

The significance of colors shall be strictly in accordance with Table 7 and, for cases which are not covered by this table, with subhead 9.3.1 and subhead 9.5. Where this is not possible with illuminated push buttons, separate push buttons and lamps shall be used.

Illuminated push buttons shall never be used for emergency stop functions nor for inching or jogging.

NOTE

Lamps that are used as indicator lights, but are designed so as to be pushed for testing the lamp, are not considered illuminated push buttons.

9.6.2 Modes of Use

- Confirmation** — When an unlighted button has been pressed, it lights as a confirmation that the order (given by pressing the button) has been received or executed. It remains lighted until a contrary order follows.

Sequence: First push the button, then the button lights.

NOTE 1

The color WHITE is usually employed in this mode.

NOTE 2

WHITE illuminated push buttons may be used with a flashing light in order to give a *double confirmation*. When the button is pressed, the light starts to flash to confirm that a starting operation or sequence or a transition period has been initiated. When this has been completed, the light automatically changes to steady to confirm that normal running conditions have been established.

NOTE 3

However, all colors except RED may be employed in the manner stated in Note 2 to confirm.

- b. **Indication** — A button is lighted to show the operator that he or she may or should press that button or in certain applications that he or she shall perform a certain task and then press the button. Reception or execution of the order (which has been given by pressing the button) is confirmed by the extinction of the light.

Sequence: First the button lights, then it is pressed.

NOTE 1

The colors YELLOW, GREEN, and BLUE are usually employed in this mode.

NOTE 2

A flashing light may be used in order to attract the attention of the operator, for example in case of an alarm. When used in such a way, the pressing of the button may change the flashing light into a steady light. In addition, the button may have the function specified under subhead 9.3.1, but no other. The steady light then remains on, until the cause of the alarm has been eliminated by separate action.

9.6.3 Application

Recommendations for the application of colors for different significations and functions of illuminated push buttons are shown in Table 7.

Table 7: Recommended Application of Colors for Illuminated Push Buttons

Color and Mode of Use	Significance of the Lighted Button	Function of the Button	Examples of Application and Remarks
Red (Indication)	Danger or alarm	STOP or OFF and in certain applications RESET (Only if this same button is also used for STOP)	

Table 7 (Cont.): Recommended Application of Colors for Illuminated Push Buttons

Color and Mode of Use	Significance of the Lighted Button	Function of the Button	Examples of Application and Remarks
Yellow or amber (Indication)	Attention or caution (or write protect)	Intervention	Some value (current, temperature) is approaching its permissible limit Pressing the yellow push button may override other functions, which have been selected previously
Green (Indication)	Machine or unit ready for operation	START or ON after authorization by the lighted button	- Start of one or several motors for auxiliary functions - Start of machine elements - Energizing of magnetic chucks or plates - Start of a cycle or a partial sequence
Blue (Indication)	Any significance not covered by the above colors and by white	Any function not covered by the above colors and by white	Indication or order to the operator to perform a certain task, for example, to make an adjustment (after having fulfilled this requirement, he presses the button as an acknowledgement)
White or clear (Confirmation)	Permanent confirmation that a circuit has been energized or a function or a movement has been started or preselected	Closing of a circuit or START or ON preselection	Energizing of an auxiliary circuit not related to the working cycle or Start or preselection - of direction of feed motion - of speeds, and so forth

NOTE

The use of RED illuminated push buttons is not recommended; however, if used, their significance shall be strictly in accordance with the requirements listed under subhead 9.3.1.

Comment: Presently, only red, yellow, white, and green LEDs are available. Blue must be high luminance to be seen, and its use should be avoided.

10 LOCATION, TYPE OF CONTROLS, INDICATORS AND ATTENDANT MARKINGS FOR DISPLAYS

The following sections describe the markings for and the types of controls and indicators used on displays and their locations.

- Control colors should be neutral. Strong red, green, yellow and amber should be avoided as those colors have safety implications.
- Controls and indicators that are likely to be used frequently should be visible and accessible from the user's normal operating position. Controls used infrequently, such as the initial setup function, may be located elsewhere. Frequently used controls are:
 - OFF/ON
 - DeGauss
 - Brightness
 - Contrast
- Markings associated with controls should be placed so that the marking is visible from the user's normal operating position.
- It is recommended that the product name, model number or name and product serial number appear on or near the front surface. This facilitates failure reporting by phone and routine inventory inspection.
- If an OFF/ON switch is used, it should be a binary function switch that indicates its state clearly. It is preferred that a rocker switch be used. The switch should be large enough to accept a male 95th percentile finger. It is intended that OFF/ON is a mains switch and is marked "O" and " | " on the switch if possible. ON should be to the right. The "O" and " | " nomenclature must have a minimum 3:1 luminance contrast ratio with the switch color. The switch should be recessed or protected to prevent inadvertent actuation. It is suggested that the OFF/ON switch be mounted on the lower-left front of the monitor/terminal.
- A green illuminated indicator should be placed on, or near, or typically above the OFF/ON switch. The indicator should come on within 0.5 seconds of switch activation. Minimum luminance is 35cd/m². Maximum luminance is approximately 100 cd/m².
- If luminance and contrast controls are put on the display, rotary controls should be used. Knobs and edge wheels are typical. See Figure 16 in subhead 7.1 for the proper direction of movement for controls based on their location and orientation. Tactile characteristics of the control surface must be appropriate for the force required to activate the control.
- Contrast should be to the left of the luminance control. If placed in a vertical orientation, contrast should be above luminance. These controls should be near each other.
- Mark placement should permit viewing the display during the operation of the controls from the user's normal operating position.
- DeGauss (if present) should be a momentary switch. It should be protected to prevent inadvertent actuation. The *crispener* symbol, DEC Symbol No. A-5059 (*DEC STD 178-5 Marking Symbolology*) is used to mark this switch. The symbol should be visible from the user's normal operating position.

- All controls may be grouped together. The preferred orientation from left to right is: OFF/ON, DeGauss, Contrast, Luminance. No top-to-bottom alignment is specified except for the previously mentioned luminance and contrast.
- The marking may be an added part, molded-in, or printed on the surface. For human legibility, alphanumeric text such as product identification and serial number should have a luminance contrast ratio of at least 3:1 with the background. Character height should be at least 8 points. *DEC STD 047-0 Bar Code Symbology* and *DEC STD 178-0 Digital Identification Marking Requirements - Introduction* and *DEC STD 178-3 Digital Marking Requirements for Completed Products Intended to Be Sold* should also be referred to for bar code or other machine-reading requirements.
- It is preferred that a mouse port, keyboard port, and other human interface ports should be easily accessible.

APPENDIX A REFERENCED DOCUMENTS

A.1 EL-Class Digital Documents

EL-Class Number	Document Title
EL-00047-00	<i>DEC STD 047-0 Bar Code Symbology</i>
EL-00066-02	<i>DEC STD 066-2 Waivers to Digital Design Standards</i>
EL-00092-03	<i>DEC STD 092-3 Finish and Color Standard - Finish Material Test Requirements</i>
EL-00102-04	<i>DEC STD 102-4 Environmental Standard for Computers and Peripherals — Product Acoustic Noise Measurement</i>
EL-00103-00	<i>DEC STD 103-0 Electromagnetic Compatibility (EMC) - Overview and Process Requirements</i>
EL-00104-00	<i>DEC STD 104-0 Product Acoustic Noise Limits</i>
EL-00107-01	<i>DEC STD 107-1 Digital Standard for Terminal Keyboards - Registry of Graphic Character Sets</i>
EL-00107-02	<i>DEC STD 107-2 Digital Standard for Terminal Keyboards—LK201 Character Sets and LK250 Character Sets</i>
EL-00119-00	<i>DEC STD 119-0 Digital Product Safety - Introduction and General Requirements</i>
EL-00119-01	<i>DEC STD 119-1 Digital Product Safety - Design Criteria</i>
EL-00120-00	<i>DEC STD 120-0 Product Thermal Design Standard: Design Requirements</i>
EL-00178-00	<i>DEC STD 178-0 Digital Identification Marking Requirements - Introduction</i>
EL-00178-03	<i>DEC STD 178-3 Digital Marking Requirements for Completed Products Intended to be Sold</i>
EL-00178-05	<i>DEC STD 178-5 Marking Symbology</i>

Use VTX SMC to order copies of EL-class documents from Standards and Methods Control. Send distribution questions to JOKUR::SMC or call DTN: 234-4423.

Note: For DEC STD 104-0, contact Product Acoustic Noise for authorization to receive this document.

A.2 Other Documents

C. Abernethy, Memorandum: "Weight, User Classes of", from *Weight and Surface Temperature*, Digital Technical Report 170, June, 1982.

C. Abernethy and K. Akagi, *LA12 Terminal Portability Report*, Digital Technical Report 156, February, 1981.

C. Abernethy, "Surface Temperature and Peoples' Responses Thereto", *Digital Equipment Corporation Memorandum*, April 1, 1981.

J.E. Farrell, "An Analytical Method for Predicting Perceived Flicker", *Behavior and Information Technology*, Vol. 5, No. 4, p. 349-358, 1986.

T.W. Faulkner, "Touching Hot Surfaces", *Consumer Products News*, Vol. 2, No. 3, September, 1976.

Van Cott, H.P., and Kinkade, R.G., *Human Engineering Guide to Equipment Design*, Joint Army-Navy-Air Force Steering Committee, American Institutes for Research, Washington, DC, 1972.

W.E. Woodson, *Human Factors Design Handbook*, New York: McGraw-Hill, 1981, p. 812.

ANSI/HFS 100-1988, *United States, American National Standard for Human Factors Engineering of Visual Display Terminal Work Stations*

ASTM E 97-82 *Standard Test Method for Directional Reflectance Factor, 45-deg 0-deg, of Opaque Specimens by Broad-Band Filter Reflectometry*

ASTM E 179-88 *Standard Guide for Selection of Geometric Conditions for Measurement of Reflection and Transmission Properties of Materials*

EF A0765 50/90 05 20 30.0 CTS *Introduction to Displays for Managers and Operators*

NOTE

The above documents are available from the Digital Library Network (DLN) Group.

A.3 Non-US Standards

United Kingdom: BS 7179, Parts 1 to 6, 1990 *Ergonomics of Design and Use of Visual Display Terminals (VDTs) in Offices*

Federal Republic of Germany: DIN 66234, Parts 1, 2, 6, and 9 *Display Work Stations*

Federal Republic of Germany: DIN 66009, *Font B for Optical Character Recognition*

Verwaltungs-Berufsgenossenschaft: ZH 1/618 10/80 *Safety Rules for VDU Work Stations in Office Areas*

Fachausschub Verwaltung: *Principles for Occupational Safety Testing of Electronic Data Processing Equipment and Visual Display Units. GS-VW-SG7*

NOTE

These documents may be obtained by contacting Human Factors Engineering.

A.4 International Standards

Draft International Standard ISO/DIS 9241-3 *Visual Display Terminals (VDTs) Used for Office Tasks*

International Electrotechnical Commission: *IEC 204-1 Electrical Equipment of Industrial Machines - Part 1: General Requirements*

IEC 73 Colors of Indicator Lights and Push-buttons

IEC 447 Standard Directions of Movement for Actuators which Control the Operation of Electrical Apparatus

NOTE

These documents may be obtained by contacting Human Factors Engineering.

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